Technical Report REMR-HY-10
April 1993

AD-A266 343

US Army Corps of Engineers
Waterways Experiment Station

Repair, Evaluation, Maintenance, and Rehabilitation Research Program

Icing Problems at Corps Projects

by F. Donald Haynes, Robert Haehnel, Leonard Zabilansky
U.S. Army Cold Regions Research and Engineering Laboratory

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Prepared for Headquarters, U.S. Army Corps of Engineers

The following two letters used as part of the number designating technical reports of research published under the Repair, Evaluation, Maintenance, and rehabilitation (REMR) Research Program identify the problem area under which the report was prepared:

	Problem Area		Problem Area
CS	Concrete and Steel Structures	EM	Electrical and Mechanical
GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

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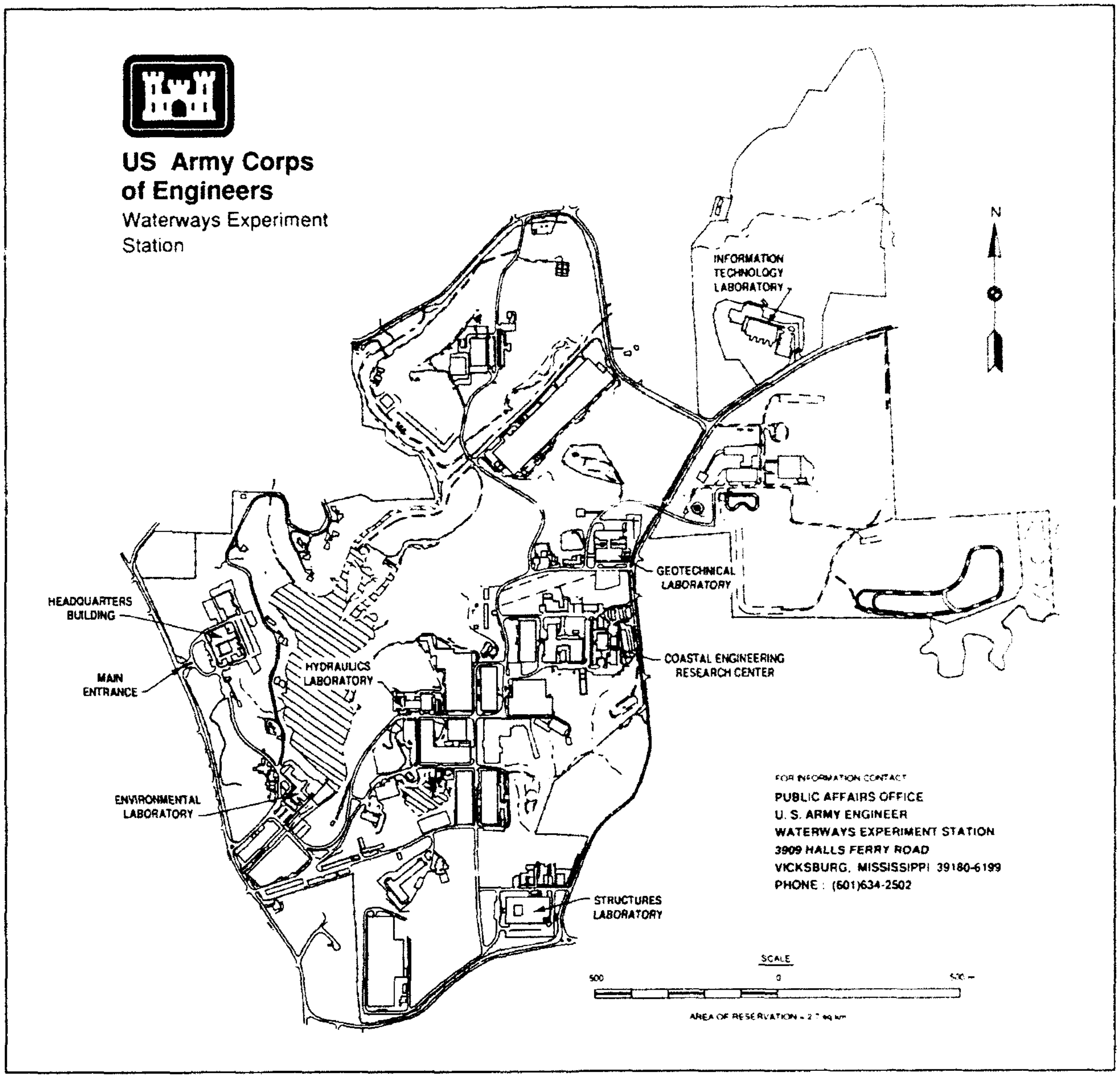
Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32659

Monitored by Structures Laboratory
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199



Waterways Experiment Station Cataloging-in-Publication Data

Haynes, F. Donald.
Icing problems at Corps projects / by F. Donald Haynes, Robert Haehnel, and Leonard Zabilansky ; prepared for U.S. Army Corps of Engineers ; monitored by Structures Laboratory, U.S. Army Engineer Waterways Experiment Station.
54 p. : ill. ; 28 cm. -- (Technical report ; REMR-HY-10)
Includes bibliographical references.
1. Ice prevention. 2. Icing (Meteorology) 3. Hydraulic gates -- Cold weather conditions. I. Haehnel, Robert. II. Zabilansky, Leonard. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Repair, Evaluation, Maintenance, and Rehabilitation Research Program. VI. Title. VII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; REMR-HY-10.
TA7 W34 no.REMR-HY-10

Contents

Preface

This investigation was performed by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) for Headquarters, U.S. Army Corps of Engineers (HQUSACE). The study was conducted under the Hydraulics Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program as part of Work Unit 32659, "Icing of Machinery Components at Corps Structures."

The REMR Overview Committee at HQUSACE consisted of Mr. James E. Crews and Dr. Tony C. Liu. The REMR Coordinator for the Directorate of Research and Development, HQUSACE, was Mr. William N. Rushing. Mr. Glenn Drummond was the Technical Monitor. The REMR Program Manager was Mr. William F. McCleese, U.S. Army Engineer Waterways Experiment Station (WES). Mr. Glen Pickering, Hydraulic Structures Division, Hydraulics Laboratory, WES, was Problem Area Leader for the Hydraulics Problem Area.

This report was prepared by Messrs. F. Donald Haynes, Robert Haehnel, and Leonard Zabilansky, under the supervision of Dr. J. C. Tatinclaux, Chief, Ice Engineering Research Branch, CRREL.

Director of CRREL during publication of this report was Dr. Lewis E. Link, Jr. Commander was COL Palmer Bailey, CE. Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
Fahrenheit degrees	5/9	Celsius degrees or kelvins[1]
feet	0.3048	meters
inches	25.4	*millimeters*

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F-32). To obtain kelvin (K) readings, use: K = (5/9) (F-32) + 273.15.

1 Introduction

Ice can cause serious problems at Corps projects across the Nation. Each year about half of the United States experiences ice formation on its rivers and lakes. At Corps projects, ice can cause machinery valves and gates to become inoperable, and these problems can require considerable effort and time to restore their normal operation. Solutions to some of the ice problems have been developed at specific projects, but in many instances these solutions are not widely known.

Carey et al. (1973) prepared a comprehensive compilation of ice problems at Corps projects. They reported that the average annual operations and maintenance costs to the Corps due to ice problems was about $13 million in 1973 dollars (an estimated $33 million in 1992 dollars). Ice problems on navigable waterways are reported as a result of a survey done by Zufelt and Calkins (1985). A survey of industry, including river users and towboat operators, was conducted by Zufelt (1986). This resulted in a compilation of ice problems on rivers, both at locks and dams and especially on river reaches between locks and dams. Many ice problems and some methods to alleviate them are discussed in EM 1110-8-1(FR) (Corps of Engineers 1990). Both structural and operational solutions are presented.

Figures 1 through 4 illustrate the types of problems that can be encountered during winter operations at Corps projects. The accumulation of ice upstream of a lock and dam is shown in Figure 1. This accumulation can result in tainter gates becoming frozen in place and therefore made inoperable, as shown in Figure 2. The roller gate, viewed from the top in Figure 3, has its chain hoist system buried in ice, which prevents it from operating. Ice accumulation on miter gates, as shown in Figure 4, can cause problems with normal operations, and in one case the added weight contributed to the failure of the top support bracket.

One ice problem at locks that has received considerable attention is lock wall icing. Hanamoto (1977) discussed several methods of alleviating this problem, including polymer coatings, high-pressure water jets, large ice saws and pneumatic devices. Although these methods met with various degrees of success, they are not used because of a lack of economic feasibility.

The purpose of this report is to give the results of a recent survey sent to all Districts and Divisions with projects that normally have ice problems. The survey builds on the past work by looking at ice problems at all Corps structures and projects affected by ice and not just those used for navigation. Both the icing problems and their alleviation methods are discussed. The chief intent of this report is to help make existing solutions and alleviation methods widely known. Lockmasters and project managers can then decide if a specific solution is applicable to a specific problem at their project. This report also looks at problems for which no solutions are known. From this focus, areas can be identified and solutions can be developed for these problems. This report is organized so that the alleviation methods for each icing problem are given in a graphical format. Many of the alleviation methods are familiar to the lockmaster or project manager. However, if a lockmaster or project manager would like to learn more about a particular alleviation method, additional information is available in the report.

2 Survey of Icing Problems

In December 1991, survey forms were sent out to Divisions and Districts for dissemination to their projects. The two-page survey is illustrated in Figure 5. This survey includes three problem areas: locks, dams, and general ice problems. Known problems are listed in the survey with spaces for respondents to add specific problems at their installation. Responses were asked for in two columns: severity and alleviation methods.

The severity categories were high, medium, and low. These categories are subjective. The basic guidance for interpretation of the categories is as follows: if an icing problem caused an interruption of operations (such as an inoperable tainter gate) and 100 man-hours were required to restore normal operations, the problem is in the high severity category if it has happened every 5 years or less. If this type of event has happened every 5 to 10 years, it could be considered medium. If this type of event has occurred every 10 years or more, it could be considered low.

At the bottom of page 1 of the survey are listed some known alleviation methods. Those filling out the surveys were asked to list the methods they used to alleviate a particular problem. If the method they were using was not listed, they were to add it to the list.

3 Survey Results

There was an excellent return of the survey, with 171 responses. From the surveys, many additional problems and alleviation methods were identified. Some of the responses were a summary of several projects within a District.

The results of the survey were entered into a database. Quite often, several alleviation methods were used to solve a particular problem. This gives an idea of the resources available at a project and some verification of the severity of a problem. For processing the results, the severity responses were converted from a high, medium, low, and none rating to a percent rating. A severity of 100 percent is interpreted as high, while a severity of zero percent is interpreted as no problems at that site. This *percent severity provides* a basis for comparing the impact of icing at Corps projects. A comparison could then be made between each problem to sort out the problems that need the most attention.

This also allowed an evaluation of how severe ice problems are in various geographical areas and how ice affects different types of projects. The frequency that various solutions were used to solve a problem was also determined. From this, the effectiveness of a solution could be assessed as well as whether or not efficient solutions are being used for that problem.

4 Impact of Icing on Projects

The percent severity for each lock project is given in Figure 6. The Corps projects are listed alphabetically under each of the Districts, which are also listed alphabetically. The highest severities are for locks in the Rock Island and St. Paul Districts.

The percent severity for each dam, which includes flood control projects and one hurricane barrier, is listed in Figure 7. The projects that have the highest severity are located in the most severe climates, e.g., those in the Alaska, Detroit, Rock Island, Omaha, and Seattle Districts.

Problems

To compare the severity of icing problems at Corps projects, a percent severity was found for each problem. The relative severity for the problems associated with locks and dams are given in Figures 8 and 9, respectively. The relative severity for general icing problems are given in Figure 10. The solutions to all these problems are shown in Figures 11-45 in the order they appear in the survey (Figure 5).

Several problems, other than the ones listed on the survey form, were identified. Since many of them had only one or no solution, they do not have a graph listing their solutions. However, some of these problems may be common to many sites, while others are site specific. The other problems were (a) ice damage to hand rails, (b) damage to piezometer casings, (c) freezing in piezometer tubes, (d) ice formation in bypass wells, (e) well float freeze-up, (f) ice blockage of air vents, and (g) well float gage freeze-up.

Solutions

The various solutions are explained in detail here, listed by similarity of solution. The general categories are operational, mechanical, heat, and manual. Operational has to do with general procedures and quite often does not involve additional equipment purchases but rather a change in some standard operating procedure. Mechanical refers to equipment or facilities added to solve the problem. Heat is similar to mechanical in that it usually means equipment is added to the project, but since there are many solutions that deal largely with heat, a separate category is necessary. Manual refers to a labor-intensive solution.

Before a full discussion of the solutions is presented, it is worth mentioning that the "no method known" option placed on the survey form has helped identify those ice problems for which alleviation methods need to be developed. In many instances, there are solutions available for those problems, but project managers may be unaware of them. This underscores the need for technology transfer between projects. There are a few problems for which there do not appear to be any solutions available. The most notable of these is ice damage to revetments and riprap. In many instances, the method used at a project was not identified on the returned survey. However, many projects gave information on these other methods under the "Other? (not listed)" category, and that information is included in this report.

Detailed information on the alleviation methods discussed here can be obtained from the individual project sites where the methods are being used. Information can also be obtained from the authors. It is hoped that solutions described in this report will be considered by Corps personnel not using them.

Operational solutions

These solutions usually do not require changes in project hardware or design but instead require changes in project operations during the winter to handle ice accumulations and icing problems.

Ice lockages. Ice lockage is the process of passing ice through the lock chamber much like locking a tow. This is effective for clearing large amounts of ice around lock and dam projects; however, ice lockage is time consuming. Ice lockage is used to remove ice in the upper and lower lock approaches, remove brash ice from the lock chamber, and remove ice in miter gate recesses. Also, ice lockage is reportedly used in removing ice buildup on lock walls, miter gates, frozen mooring bits, and gate machinery. Alternative and/or complementary solutions include the use of bubblers in the upper lock approach, passing ice over spillways, and diverting ice towards nearby tainter or roller gates. In some cases, these gates can be opened to create a diversionary flow.

Increased tow entrance speed. In this method, the tow is brought into the lock at an increased speed to "run over" the ice that is in the lock chamber. It has the potential advantage of moving less ice into the lock than normally would be brought in with a tow. When a tow is moved into a lock, water has to flow out of the lock. The volume of water displaced by the submerged position of the tow is moved out of the lock. In some cases, this can cause ice to be carried out with the flow of water. Increasing the tow entrance speed can increase the velocity of this water flow. However, it gives the towboat captain less control, and therefore there is more potential for damage to the lock wall and gates. This method is used for handling ice in the upper lock approach and removing ice from the bottom of barges.

Emergency bulkhead used as spillway. This method is done by one of two ways. One way is to install the emergency bulkhead, or stop logs, in front of a dam control gate to break up the ice and allow easy passage of the smaller pieces under the gate. The authors have seen this done for passing ice under a roller gate on the Mississippi River. A 3-ft[1] waterfall was created and was effective in breaking up the ice. The other way is to raise the emergency bulkhead lift gates upstream of the miter gates so that the bulkhead acts as a spillway to pass ice into the lock. The authors have seen this method used on the Ohio River with good success. For many locations this is a simple and effective solution used to reduce ice in the upper and lower lock approaches and miter gate recesses.

Barges used as deflectors. Diverting ice can be an effective technique if barges are available. In this method, barges are strategically positioned to deflect incoming ice so that it can be passed over the dam by auxiliary locks, gates, or spillways on the dam. Typically this is used to deflect ice away from the upper lock approach. This is used on the Ohio and Mississippi rivers. Because it ties up barges, it is customarily used only on a short-term basis.

Gate fanning. Fanning or continual movement of miter gates can be an effective way to move ice out of the miter gate recesses. When used in conjunction with a point source bubbler or flow inducer, it can be very effective. However, it is typically time consuming to fan the gates, and large quantities of ice typically are not efficiently handled this way. Air bubblers in the recesses are a more effective way to handle large accumulations. Miter gate fanning is used to remove ice from the upper and lower lock approaches, lock chambers, and miter gate recesses. It is also used at a few sites to reduce ice buildup on miter gates and to prevent freeze-up of gate machinery.

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[1] A table of factors for converting non-SI units of measurements to SI units is presented on page v.

Restricting tow width/size. Tow size restrictions are often imposed because ice conditions reduce the effective size of a lock. This can happen when ice builds up on lock walls extending 2 to 3 ft out into the chamber or from ice buildup on the gates, preventing them from becoming fully recessed. Tow sizes can be reduced from the standard three-barge, 105-ft width down to the two-barge, 70-ft width. Where possible, it is desirable to avoid tow restrictions by the use of bubblers, heaters, or some other solution, since reducing the tow width affects the tonnage and economy of the shipping operation. However, it does enable the shipping operation to continue during the winter. These restrictions can be imposed as a result of ice accumulation in the upper and lower lock approaches, miter gate recesses, and lock chamber; ice buildup on lock walls and miter gates; and ice on the bottom of barges.

Removing from service. Removing machinery from service is an option that has been exercised at some projects. In some cases, this may simply mean shutting down some optional equipment or machinery that is not critical to the project, which may be an acceptable solution for the duration of the winter. The typical equipment removed from service are mooring bits and frozen dam gates. However, in at least four cases noted in the survey, the entire lock project was shut down during the period of severe ice conditions. The sites that reported a shutdown were located on the Atlantic Intracoastal Waterways, where severe ice conditions are seldom seen.

Towboat assistance to break ice. Towboats from both the Corps and industry are often used to break up and divert ice. In many cases, the use of a towboat to break ice is the only readily available method. Their effectiveness depends upon the ice conditions, such as thickness, strength, extent, and floe size, and upon the towboat size. However, towboats may be unavailable, and their use is time and energy consuming. There is a hazard to personnel and property when towboats are used to break ice. If the ice starts moving while the boat is trying to break up a floe, the boat can become caught in the jam, can be carried up against a dam, and can capsize or sink. Towboats have been used to break up ice in the upper and lower lock approach and remove brash ice in lock chambers and miter gate recesses. At one lock and dam, as many as four towboats have been used concurrently to move ice towards the dam gates. This is sometimes done by backing the towboat downstream towards the gates. Towboats are also used to remove ice buildup on lock walls, to break ice around frozen floating mooring bits, and to dislodge ice from barge bottoms.

Change gate position and continual movement of gates. These methods, also known as "exercising" the gates, are used to prevent gates and machinery from freezing and becoming inoperable. The main difference between a change in gate position and continual movement of gates is the frequency of movement. The pool level is unaffected by a change in gate position if two dam gates are concurrently moved in opposite directions the same distance and at the same rate. Continual movement of gates can mean to periodically move the dam control gate some short distance and

then bring it immediately back to its original setting, which essentially does not affect the pool level. The frequency of gate movement is dependent upon the air temperature and the ice and river stage. In general, however, as the air temperature decreases, the gates should be exercised more often. As a guideline, one site in the Rock Island District has had good success with exercising the tainter gates about 6 in. every hour when the air temperature is below -10°F. At another site, the gates are moved every 8 hr when the temperature reaches 0°F. At most sites, this is a relatively simple method to ensure that the gates will remain operational. The disadvantages are that it can be time consuming and labor intensive. At locks, the valves are exercised to prevent freeze-up of the valve machinery. Around dams, gate changes are used to reduce ice accumulation upstream of dam and ice arching between piers. Also it is used to reduce ice buildup on upstream and downstream pier walls, reduce icing on gate skin plates and structural elements, and prevent freezing of side or bottom seals. Exercising the gates is used to prevent icing on lifting cables and chains and freeze-up of lift machinery. This is also used to allow passage of ice during low-flow conditions, to reduce hazards to personnel, to prevent brash and frazil ice blockage at intakes, to reduce ice forces on structures, to keep ice from interfering with debris removal, to prevent instrumentation freeze-up and to reduce ice floe impact loads.

Sand, salt, etc. Sand, rock salt, and other ice-melting compounds are used at many sites to reduce icing of walkways and other ice accumulations that cause hazards to personnel. Ice cleats, or crampons, are commonly used for walking on ice and snow accumulations.

Flushing water. Flushing water is used at locks to flush ice out of problem areas (refer also to hydraulic assist). This can be done in two ways. To flush ice out of the chamber, the upstream valves are opened and the downstream miter gates are opened. The water flow then can flush ice out of the lock chamber. This can also raise the water level in the lock chamber. For this reason, flushing water can be used to lift a barge with ice accumulated on the bottom of it over the downstream sill. Often the jet of water hitting against the barge hull will also knock ice loose, which can help remove ice from the barge bottom. The second way is to have both the upstream and downstream miter gates closed and the upstream and downstream valves open. This jets water into the lower approach area, removing ice from the lower approach. This method has been used by the Rock Island District.

Ice coupling. This is a method of connecting two barges so that the two raked bows face each other. This allows a place for ice to go when the barges are re-coupled, allowing a snug connection to be made easily. This is especially useful when a tow has to be broken in order to lock it through. Ice coupling is used to reduce ice on the bottom of barges, and it helps prevent brash ice in the lock from limiting the tow size.

Filling and emptying lock chamber. Filling and emptying a lock chamber has been used for flushing ice out of the miter gate recess and out from under barges. Bringing water into the lock chamber can also help break up thin ice sheets, which can then be flushed out of the lock.

Draining water pipes. Draining water pipes has been seasonally used to eliminate water pipe freezing. This can be done by simply gravity feed draining, or in some cases the pipes can be blown out with compressed air.

Leaving water running. Leaving water running is one way tc prevent water pipes from freezing during winter operation.

Restricting intake flow. Restricting the intake flow can be used to prevent ice blockage of intakes. However, at hydroelectric projects this is not usually desirable, so for such projects the intake flow can be restricted long enough to allow a stable ice cover to form upstream. This stable ice cover will reduce the production of frazil and brash ice, which can block water intake trash racks. Then normal flow may be resumed. For lock projects, restricting the intake flow may sometimes be a good option, even though it may slow the filling and emptying of the chamber. In this case the reduced intake flow may help form a stable ice cover upstream of the lock and reduce the frazil drawn into the lock.

Covering air intake for tunnel operation. This refers to dams that are constructed with tunnels for discharge passages, as is often the case at dam projects in the Huntsville District. Here cold air is often drawn down into the air intake vents, and this can cause the water to chill and freeze-up the dam valves. Covering the air intake prevents freezing of the dam valves. However, operation of tunnels with air vents covered can cause structural problems as a result of high vacuum. This method of operation should be done only after an engineering review of the situation has been made and approved.

Sealing leaks on dam gates. Sealing the leaks on dam gates can effectively reduce the buildup of ice on pier walls and seals. This also helps reduce icing of the structural elements of the gates. This has been used in both the Portland and Rock Island Districts.

Greasing mooring bits. Greasing mooring bits has been used to prevent ice buildup on floating mooring bits with limited success. This technique may be successful only in less severe climates.

Keeping pool level low. The pool level is kept low in the lock chamber at some sites to keep the water away from the gate and valve machinery. This prevents the freeze-up and icing of this machinery.

Maintaining winter pool at high elevation. This method, used at some dam sites, helps to reduce icing of gate skin plates, walls, seals and structural elements. This also prevents freeze-up or icing of gate machinery and lift cables and chains.

Towboat wheel wash. This is commonly used to move ice out of the upper approach and lock chamber. This can be time consuming and removes the towboat from its normal operation. However, when brash ice accumulations prevent tow passage, this method may be the only expedient method available.

Mechanical solutions

These solutions often involve the purchase and installation of hardware and equipment. In some cases they may also require modifications to existing projects. However, the costs incurred by these solutions are usually offset by the huge reduction of time required to handle ice problems.

Air bubblers. Air bubblers are successfully used to move ice and reduce ice growth. They can either be installed as a point-source bubbler or an air curtain. Air bubblers are easy to use, and a bubbler system can be designed and operated to meet the special needs of a particular site. Many sites typically rent 750-cfm compressors for the winter to handle the air requirements for these bubblers. Usually one compressor is used for the upper miter gate area and one for the lower miter gate area. A typical rental cost for a compressor from December to March is about $4000. Recent lock and dam rehabilitation work in the Rock Island District includes air bubbler feed lines installed. These have easy hookups for rented air compressors. A description of a complete bubbler system is given in EM 1110-8-1 (FR) (Corps of Engineers 1990). They are used to control ice in the upper and lower approaches and the lock chamber. Air bubblers are effective at removing ice from miter gate recesses and barge bottoms. Also, air bubblers can be used to reduce ice buildup on lock walls, miter gates, frozen mooring bits and valve machinery. If there is a source of heat, such as a submerged heat cable or slightly warmer water at the bottom of the pool, bubblers can be used to move the warm water and prevent ice growth.

Ice piers. Ice piers are bottom-founded gravity structures and can be very effective at breaking up ice floes and reducing ice forces on structures. However, they are expensive to construct. They have been used to reduce or break up ice in the lower lock approach, reduce ice upstream of a dam, reduce ice arching between piers, and allow ice passage during low-flow conditions. Ice piers are also used to reduce ice floe impact loads.

Water jets. Water jets or flow inducers have been used to reduce freezing around some structures. The warmer water from the bottom is brought to the surface and directed at a problem area. This warmer water retards the growth of ice around dam piers, gate seals, and gate structural elements. At the Soo Locks, a method is used to control ice buildup in the quiescent zone of water between the downstream side of the upper miter gates and the location of the filling ports. Ice flushing jets have been installed in the Poe Lock. These jets consist of a 24-in.-diam by 4-ft-long

pipe through the miter gate with a 24-in. butterfly valve for flow control. This system allows water from the upper pool to flush out the quiescent zone during icing periods.

Intakes below ice depth. This method helps to prevent water intake blockage due to frazil or brash ice. This of course is a design consideration that needs to be addressed before construction, since intake locations are not easily changed after the project is completed. To know how de (l) the intakes need to be installed, the thickness and extent of the ice as well as the flow velocity at that location has to be determined. If intake blockage due to frazil ice may be a problem, the intakes should be as deep as the design allows.

Burying water pipes. Burying water pipes below the frost line is a common method to prevent freezing of water pipes. Considerations in this method are local frost depth and accessibility of the water line.

Insulating water pipes. This method is effective for preventing freeze-up of pipes that are directly exposed to cold air. Often with this method, some heat tape may also be added as an extra precaution.

Plywood covers. Plywood covers have been used to prevent freeze-up of project machinery. In some cases a flat piece of plywood, with or without insulation, placed over the valve pit is effective in preventing freeze-up and icing of valve machinery. Also small heated structures made of plywood or metal are placed over the gate, valve, and other machinery to prevent icing and freeze-up.

Electric motor overload protection. Overload protection is very important when dam gates are covered with ice and the added weight prevents the electric motor drives from moving them. This protection avoids motor damage and keeps the gates operational in the winter. However, the ice must be removed from the gate structural members in order for the motor-driven lift machinery to operate.

Ice gate. An ice gate is a spillway specifically designed for ice passage. This would be located so ice can be easily drawn out of the problem area, such as the upper lock approach, around the bullnose and over the ice gate. This could be particularly useful at sites where the dam gates are not far removed from the lock and passage of ice through the dam is not difficult. Although no known ice gate has been installed to date, this has been recognized as a possible solution to ice accumulation problems for some time. An ice gate could be a gate located near a lock that would enable passage of ice from the upper approach.

Increasing size of drift pass. Drift passes at some sites are used for passing ice. Sometimes a towboat will use its wheel wash to push ice towards the drift pass. Increasing the size of the drift pass may be a good solution at many lock sites for handling ice accumulations upstream of the lock and preventing ice from entering the lock. In this design the existing

drift pass in a guidewall used for debris removal is enlarged or additional ones added to accommodate passage of large quantities of ice out of the upper lock approach area. This could be used in conjunction with the ice gate concept. This concept has not been used at any known project, but it could be applied at some sites.

Heat solutions

These solutions use heat to control ice problems at Corps projects. Like the mechanical installations these options may require purchasing and installing hardware. The operating costs will vary with the demand, and this should be considered in any installation.

Steam application. Steam is often used to remove ice from surfaces and machinery. The steam can be supplied from an onsite generator or from a small, portable steam generator. Although this is preferred over more labor-intensive methods such as pike poles, it can still be very time consuming. Steam application has been effectively used in removing ice from lock walls and miter gates. It has also been used for de-icing frozen gate and valve machinery. Many projects have a boiler and delivery lines extending across the dam, with valve access at each tainter gate. Tee bars and wands are typically used to apply steam to the icing areas, e.g. tainter gate side seals. At many locations, steam is used from 3 to 6 weeks every winter. However, the application of steam can be virtually ineffective below 0°F. At the Soo Locks, plywood panels have been installed on the downstream side of the miter gates with steam lines placed on the inside of the gate. This provides heat to prevent buildup of ice on the upstream gate face and facilitates securing the gates in the recesses.

Electric heaters. Electric heaters are widely used to alleviate icing problems at Corps projects. Electric heaters are usually easy to install and operate. Because they are available in a wide variety of shapes, sizes, and power ratings, they are adaptable to many icing problem areas. The configurations include strip heaters, radiant heaters, heat tape, and spotlight heaters. However, they can consume considerable electrical power, and unless power is relatively inexpensive, this could be an obstacle to their use. At locks, electric heaters are used to reduce ice in the upper approach and in miter gate recesses, de-icing frozen floating mooring bits and preventing freeze-up of valve machinery. At dams, they help to keep gates operational by preventing freeze-up of gate machinery, cables and chains, gate surfaces, seals and structural elements, as well as eliminating ice on downstream pier walls.

The authors have been involved in the successful use of J-seal heaters at several sites in the Rock Island District. Self-regulating heat cables (1/2 × 1/8 in. in cross section) are installed in hollow core J-seals. They are rated at 20 W/ft with 120 V and 37 W/ft with 240 V. Because they are small, two cables can be placed in the J-seal hollow core to increase the heat. These heaters keep the rubber J-seals flexible in low air

temperatures and enable them to maintain a tighter seal against the side plates. In some cases, the use of J-seal heaters has not been totally successful. This is probably due to insufficient heat applied at low air temperatures. Also the authors have been involved with the analysis of skin plate heaters for tainter gates in the St. Paul District. It is important to specify in the design of electrical resistance heaters that they be replaceable. They can sometimes burn out and short, so placement inside a pipe or structural tubing, for example, is essential for replacement. Infrared radiant heaters have been used in both the St. Paul and Rock Island Districts for de-icing the roller gate chain drives shown in Figure 3. At one site on the Mississippi River, ice has accumulated up to 4 ft thick on the chain drive. At another site, the use of infrared radiant heaters has kept the cogs free of ice at air temperatures of 0°F.

Electric heaters have been used to prevent ice blockage at water intakes due to both frazil and brash ice accumulations. Surface electrical heating of the upstream edge of trash rack bars has been developed at the U.S. Army Cold Regions Research and Engineering Laboratory. A field test at a small hydropower plant showed that a heated trash rack could be kept clear of frazil ice while adjacent unheated racks became blocked. Detailed information on intake trash rack heaters is found in Daly et al. (1992).

Electric heaters are also used to prevent hazards to personnel, to protect water pipes from freezing, and to protect project machinery. Electric heaters are used to reduce ice forces on structures, to prevent ice interfering with debris removal, to reduce spillway icing, and to prevent freeze-up of instrumentation.

Oil seal heaters. This method consists of pipes placed in pier walls with heated oil pumped through them to prevent freeze-up of side and bottom seals on dam control gates. However, this method has been generally plagued with oil leaks and is not recommended.

Hot water application. Hot water is used much like steam to de-ice project components. However, it is usually time consuming and labor intensive. It is often used as a curative rather than a preventive method of solving ice problems. It may be more cost effective to use ice preventive methods such as electric heaters instead of hot water. The use of this method depends upon the availability of the hot water, the location of the problem area, the water drainage, and sufficiently high air temperatures so that the hot water does not create its own ice problem. Hot water from a "Hotsy" high-pressure hot water washer is used at several sites to remove ice from miter gates. The water from these portable kerosene burner units is typically 200°F. Water for the units can be taken from the river or from wells. Hot water application is used on locks for reducing ice in miter gate recesses and ice buildup on miter gates, floating mooring bits, check pins, and gate and valve machinery. Additionally intakes blocked with frazil or brash ice are cleared with hot water. Around dams, hot water is used to reduce ice arching between piers; to remove ice from gate skin

plates, side or bottom gate seals, and gate structural elements; and to prevent freezing of lifting cables and chains and lift machinery. Under general ice problems, hot water is used for freeze protection of water pipes, de-icing walkways and instrumentation, as well as to eliminate other ice accumulations causing hazards to personnel.

Gas heaters. Gas heaters in various forms are used to alleviate ice problems at lock and dam projects. Salamander-type forced hot air heaters are used at several sites to prevent freeze-up of gate and valve machinery, including gear boxes. It is essential that the hot air be applied directly at the machinery. This can usually be done with a flexible duct. Gas heaters are also used to prevent freezing of water pipes. Sometimes gas torches are used to thaw out frozen water pipes and can be used for de-icing machinery. Thawing out frozen machinery can be time consuming. Therefore, consideration should be given to preventing freeze-ups, both in rehabilitation programs and in new designs.

Manual solutions

These methods are typically very labor intensive and time consuming. The hardware involved is usually very inexpensive compared with the labor costs. Design and rehabilitation rationale should consider eliminating the need for these manual methods as much as practicable. This rationale involves preventing the formation of ice rather than removing ice.

Compressed air lances. Compressed air lances have been used for de-icing surfaces and machinery, but their effectiveness is limited. They may be useful at projects where ice is not a severe problem and only spot removal is necessary. This, however, is contingent upon the availability of compressed air, from either an installed or a portable compressor. Since this is a very slow method of removal, other methods of heat application may be a more efficient use of resources. Probably the most effective use of compressed air is removing water from water pipes to avoid freezing of the pipes in winter. Air lances have also been used at a few sites to remove ice from frozen dam gates and lock valves and to de-ice spillways. Also they have been used to remove brash ice and frazil ice blocking intakes.

Pike poles. Pike poles are widely used to remove ice and debris from Corps structures. They are effective for spot removal of floating ice chunks and ice accumulations. However, they are not recommended for handling large quantities of ice because the use of pike poles is labor intensive and can be a hazard to personnel. In cases where large amounts of ice accumulate, as in midwinter conditions, solutions such as bubblers, electric heaters, or ice lockages will be a more efficient use of resources. They are commonly used in conjunction with ice lockages and bubbler operations, especially in miter gate recesses. Pike poles have been used to remove ice in upper and lower lock approaches, miter gate recesses, and lock chambers. Also, pike poles are used to remove ice from lock walls,

miter gates, tainter gates, and barge bottoms. Pike poles are used to free frozen mooring bits, check pins, and other gate and valve machinery.

Ice rakes. Ice rakes are used to move and clear ice from problem areas. This is effective for spot removal but is labor intensive and is not recommended for removal of large ice accumulations. Where possible, air bubblers or other solutions may be more efficient means of ice removal. Ice rakes have been used to remove ice from the upper lock approach, miter gate recesses, and the lock chamber.

Chipping. Chipping ice, with whatever type of chipper, is a time-honored method of removing ice and is widely used. However, it is very labor intensive, and it is commonly used for removing small areas of icing. In many instances, heat application in various forms may be a more efficient use of resources. Chipping ice has been used to remove ice from lock walls, miter gates, floating mooring bits, check pins, and other gate and valve machinery. It also has been used to remove ice from walkways and in some instances from the upper lock approach.

Saws. Saws have been used to remove ice from lock walls, miter gates, and gate skin plates. Saws can be electrical, mechanical, or hand. Large chainsaws have been used to remove ice from lock walls. They are usually very slow, cutting 1 to 3 ft/min. Problems with using saws are that they may damage a structure or machinery component and also may damage the saw.

5 Conclusions

A survey was distributed to Divisions and Districts that usually have problems with ice. There was an excellent response, with 171 returns of the survey. From the results, a wide variation in severity of ice problems across the nation was found. The severity depends upon the climate and the amount of ice grown at a site or upstream of a site. It also depends upon the frequency of severe weather, the resources at a site to contend with the ice, and the normal winter operations at a site.

Graphs of the 35 most common problems at locks, dams, and other Corps projects are presented. On the same graph are listed the alleviation methods or solutions to a particular problem. Solutions are separated into four categories: operational, mechanical, heat, and manual.

The purpose of this report is to provide technology transfer. Additional information on the solutions can be obtained from a project or Corps District where the solution has been implemented or from the authors. Knowledge of existing solutions has and can lead lockmasters, project managers, and District engineers to implementing these solutions. The rationale for the design or rehabilitation of a project should consider methods for preventing the formation of ice in problem areas. This is in contrast to the removal of ice after it has formed. Many manual methods now used should be eliminated wherever possible. The survey results also showed a need to develop new solutions to many icing problems that still prevent Corps projects from operating efficiently during winter conditions.

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Figure 1. Ice upstream of Lock and Dam 20, Mississippi River

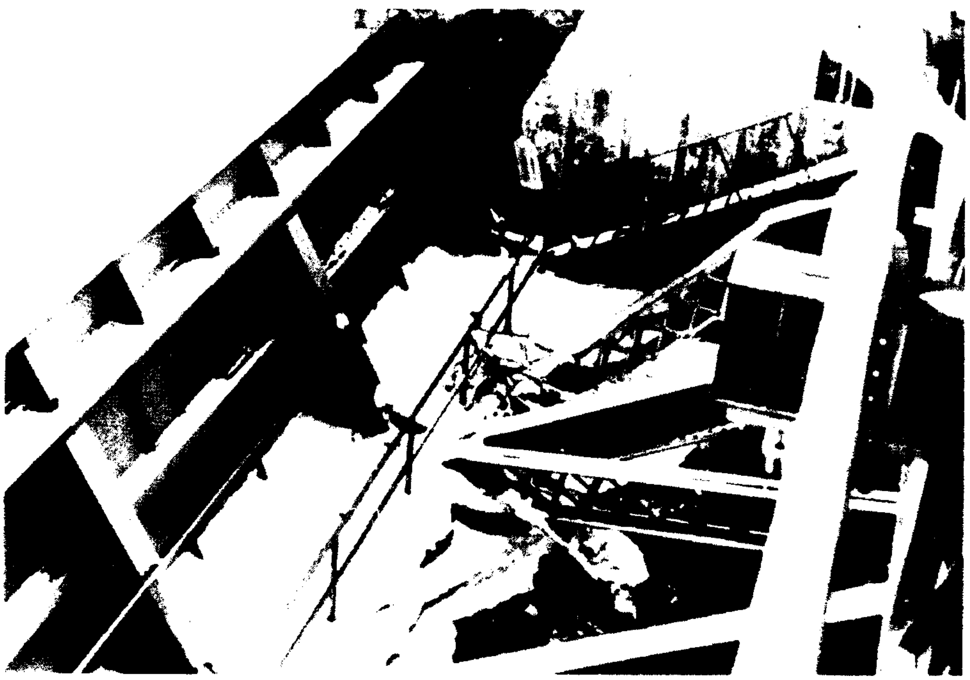

Figure 2. Ice on a tainter gate

Figure 3. Ice on the chain hoist of a roller gate

Figure 4. Ice on a miter gate

Survey of Corps Project Ice Problems

Project name ____________________

Address ____________________

River ____________________ Mile ________ District ____________________

Problem number		***Severity*** H = High M = Medium L = Low	***Alleviation method*** Enter number of method listed below
Ice problems at locks			
1	Ice in the upper approach		
2	Ice in the miter gate recesses		
	Ice buildup on lock walls		
4	Ice buildup on miter gates		
5	Frozen mooring bits		
6	Ice accumulation on check pins		
7	Freeze-up of gate machinery		
8	Freeze-up of valve machinery		
9	Icing of walkways		
10	Ice in the lower approach		
11	Ice on barge bottom surfaces		
12	Brash ice in lock limiting tow size		
13			
14			
15			
Ice problems at dams			
16	Ice accumulation upstream of dam		
17	Ice arching between piers		
18	Ice buildup on upstream pier walls		
19	Ice accumulation on gate skin plates		
20	Freezing of side and/or bottom gate seals		
21	Ice accumulation on downstream pier walls		
22	Ice accumulation on gate structural components		
23	Ice accumulation on lifting cables and chains		
24	Freeze-up or overload of lifting machinery		
25	Ice passage during low flow conditions		
26	Gate freeze-up preventing opening on short notice		
27			
28			
29			

1. Ice lockages
2. Increased tow entrance speed
3. Emergency bulkhead used as spillway
4. Air bubblers
5. Barges used as deflectors
6. Gate fanning
7. Steam application
8. Compressed air lances
9. Pike poles
10. Chipping
11. Electric heaters
12. Restrict tow width/size
13. Remove from service
14. Hot water application
15. Towboat assistance to break ice
16. Change gate position
17. Continual movement of gates
18. Ice piers
19. No method known
20. Other? (not listed)

Figure 5. Survey of Corps project ice problems (Continued)

Survey of Corps Project IceProblems (cont'd)

Problem number		*Severity* H = High M = Medium L = Low	*Alleviation method* Enter number of method listed below
General ice problems at Corps installations			
30	Freeze protection of water pipes		
31	Freeze protection of machinery		
32	Ice accumulation causing hazards to personnel		
33	Brash ice blockage at intakes		
34	Frazil ice blockage at intakes		
35	Ice forces on structures		
36	Icing problems with debris removal systems		
37	Valve freeze-up or icing problems		
38	Spillway icing		
39	Freeze-up on instrumentation, antennas, etc.		
40	Ice floe impact loads		
41	Ice damage to revetments, rip-rap, dikes, etc.		
42			
43			
44			
45			

1. Ice lockages
2. Increased tow entrance speed
3. Emergency bulkhead used as spillway
4. Air bubblers
5. Barges used as deflectors
6. Gate fanning
7. Steam application
8. Compressed air lances
9. Pike poles
10. Chipping
11. Electric heaters
12. Restrict tow width/size
13. Remove from service
14. Hot water application
15. Towboat assistance to break ice
16. Change gate position
17. Continual movement of gates
18. Ice piers
19. No method known
20. Other? (not listed)

Name, title, address, and phone number of the person completing this survey:

____

____

____

Return to: Donald Haynes
USACRREL
72 Lyme Road
Hanover, NH 03755-1290
Phone (603) 646-4184
Fax (603) 646-4477

Thank you.

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Figure 5. (Concluded)

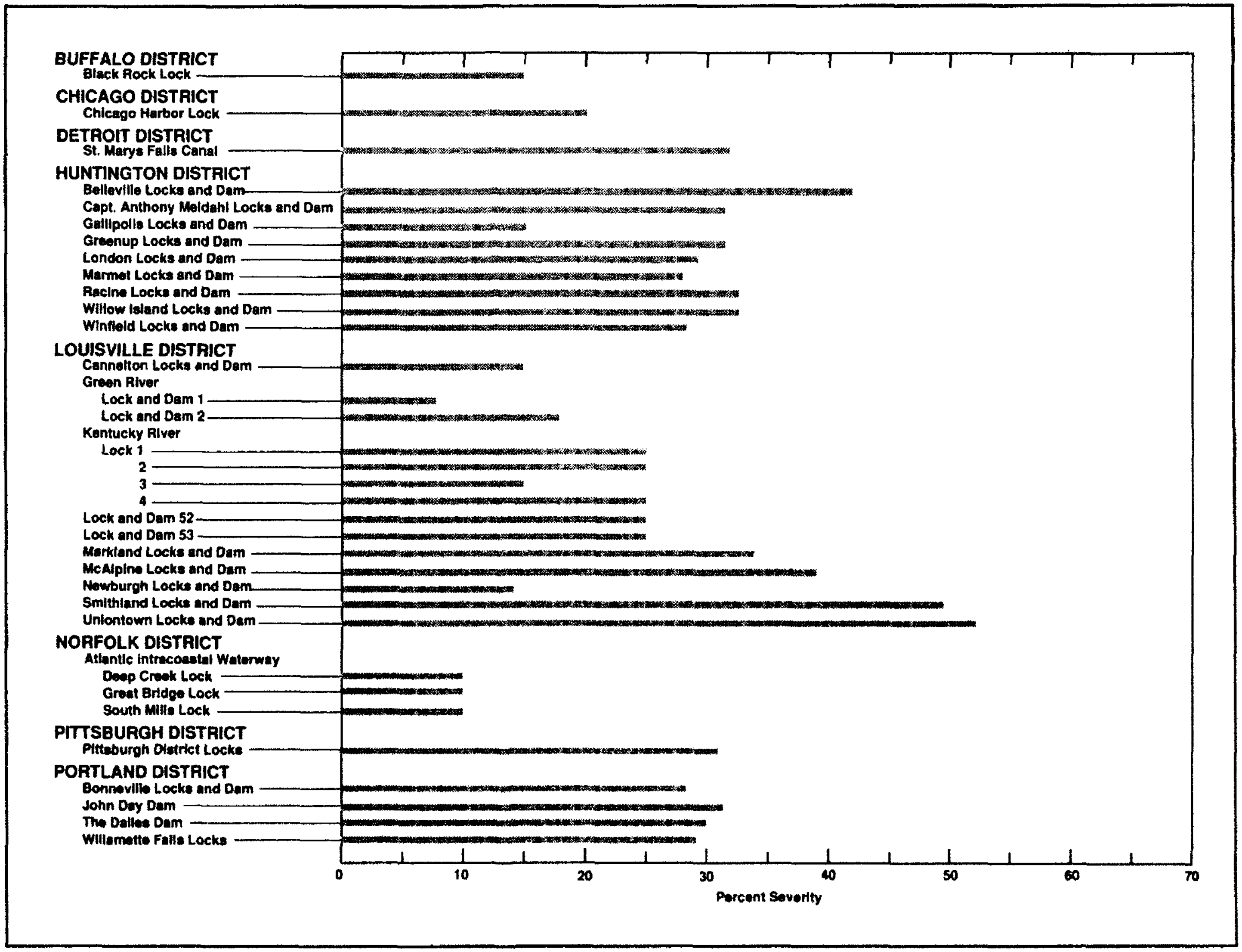

Figure 6. Percent severity for ice problems at locks (Continued)

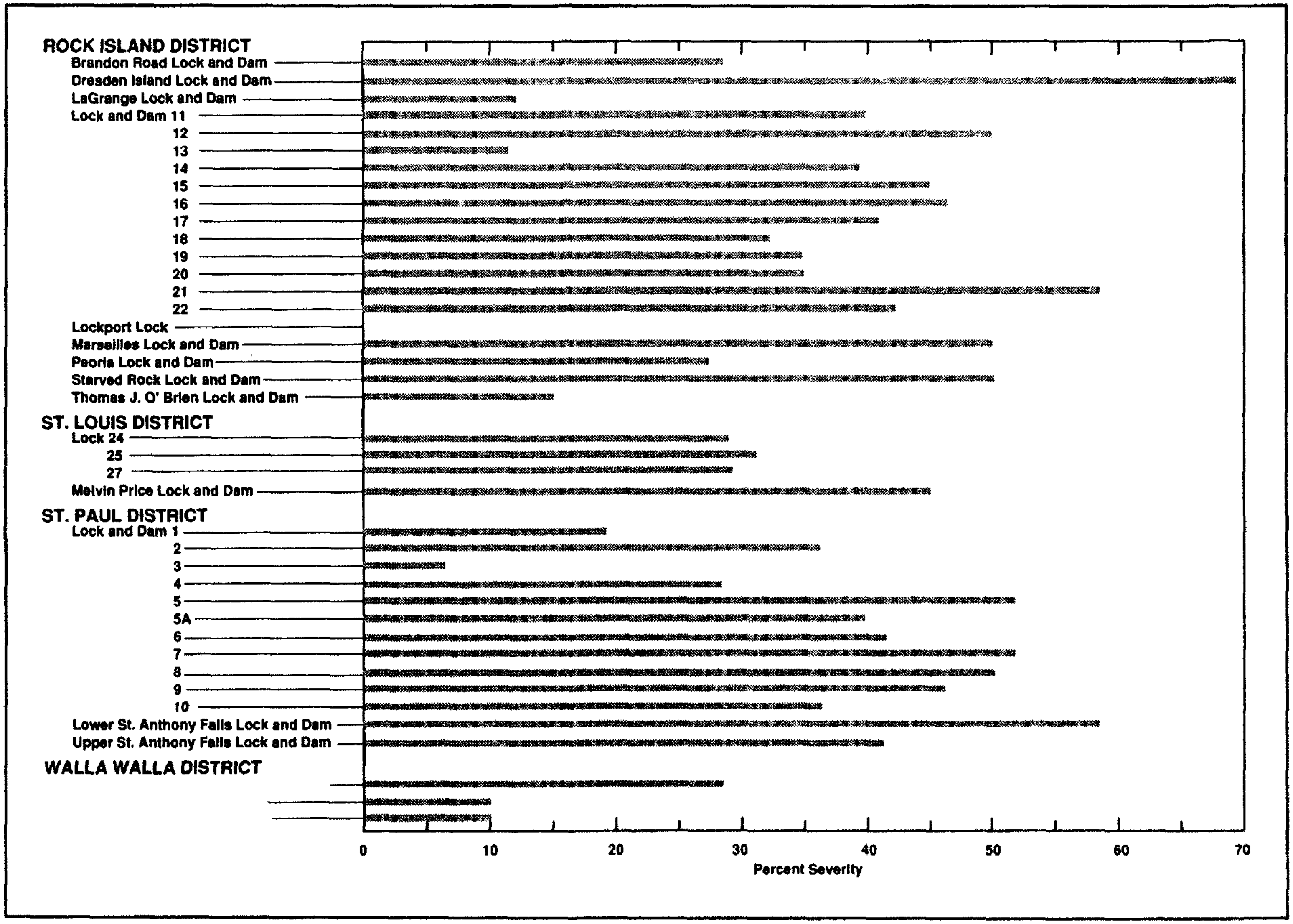

Figure 6. (Concluded)

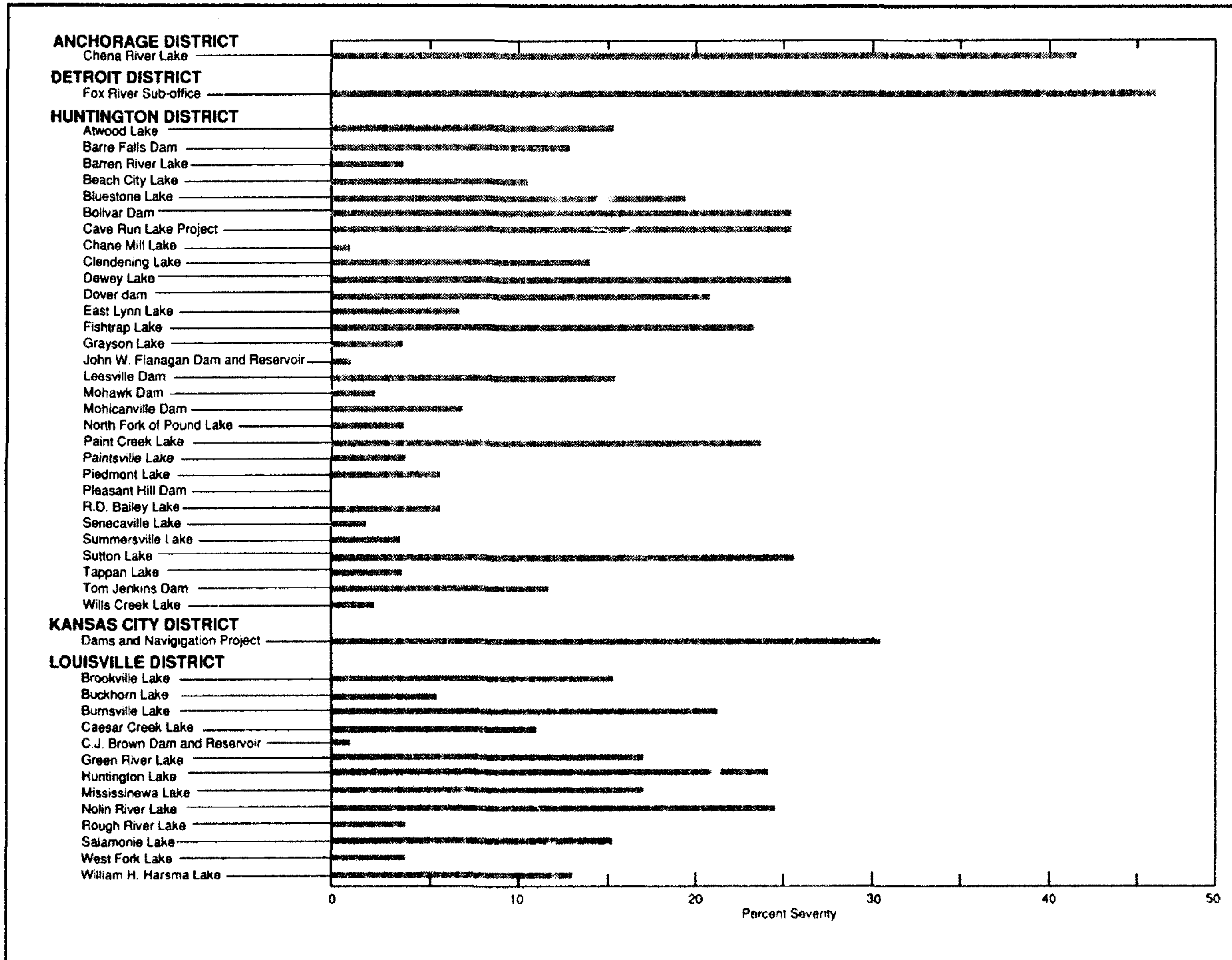

Figure 7. Percent severity for ice problems at dams (Continued)

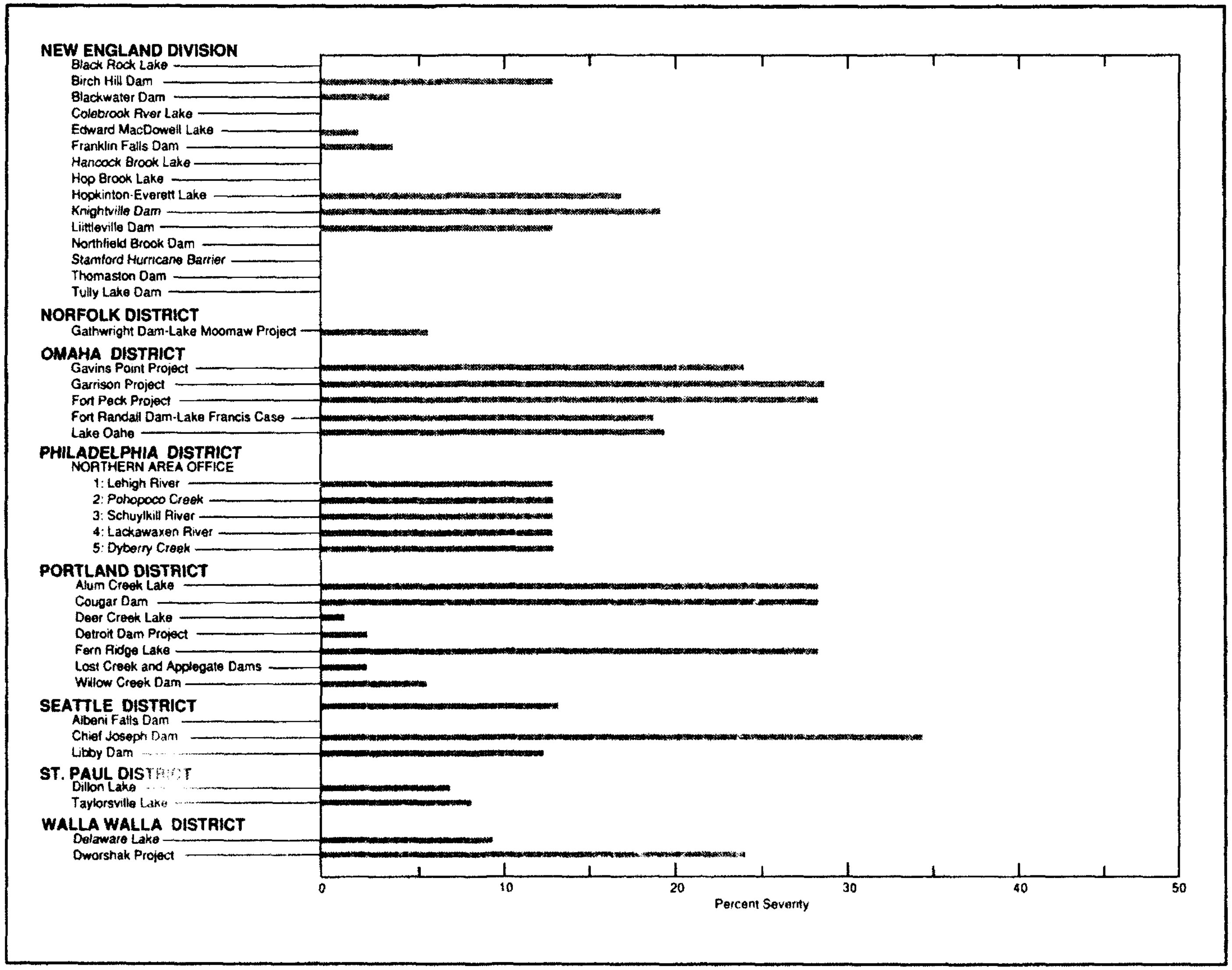

Figure 7. (Concluded)

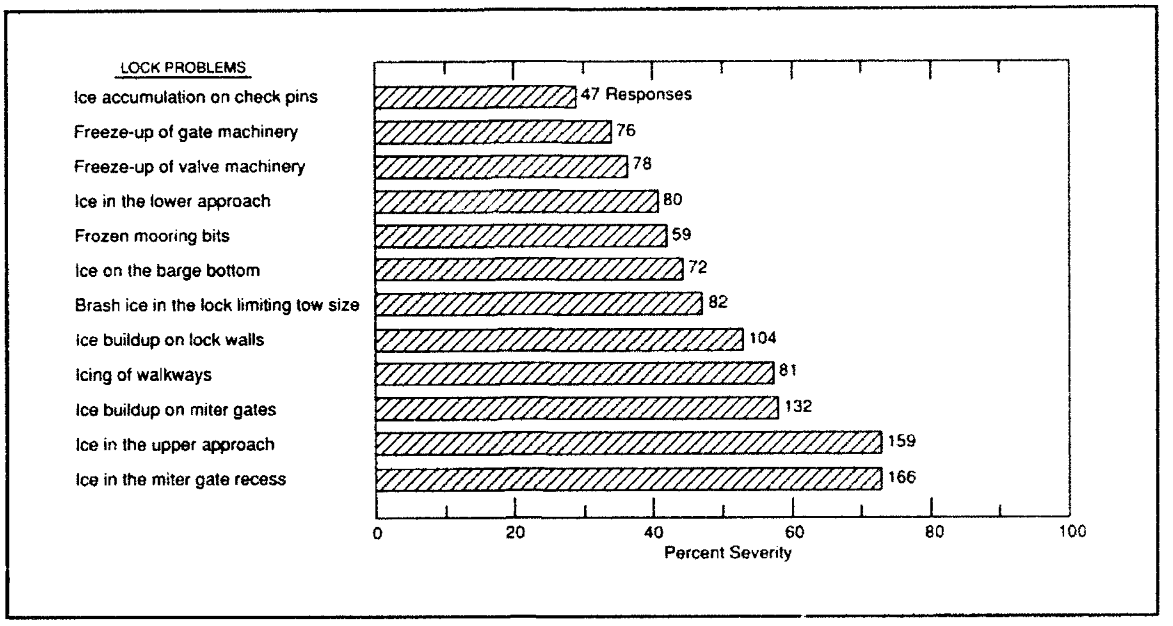

Figure 8. Severity of ice problems at locks

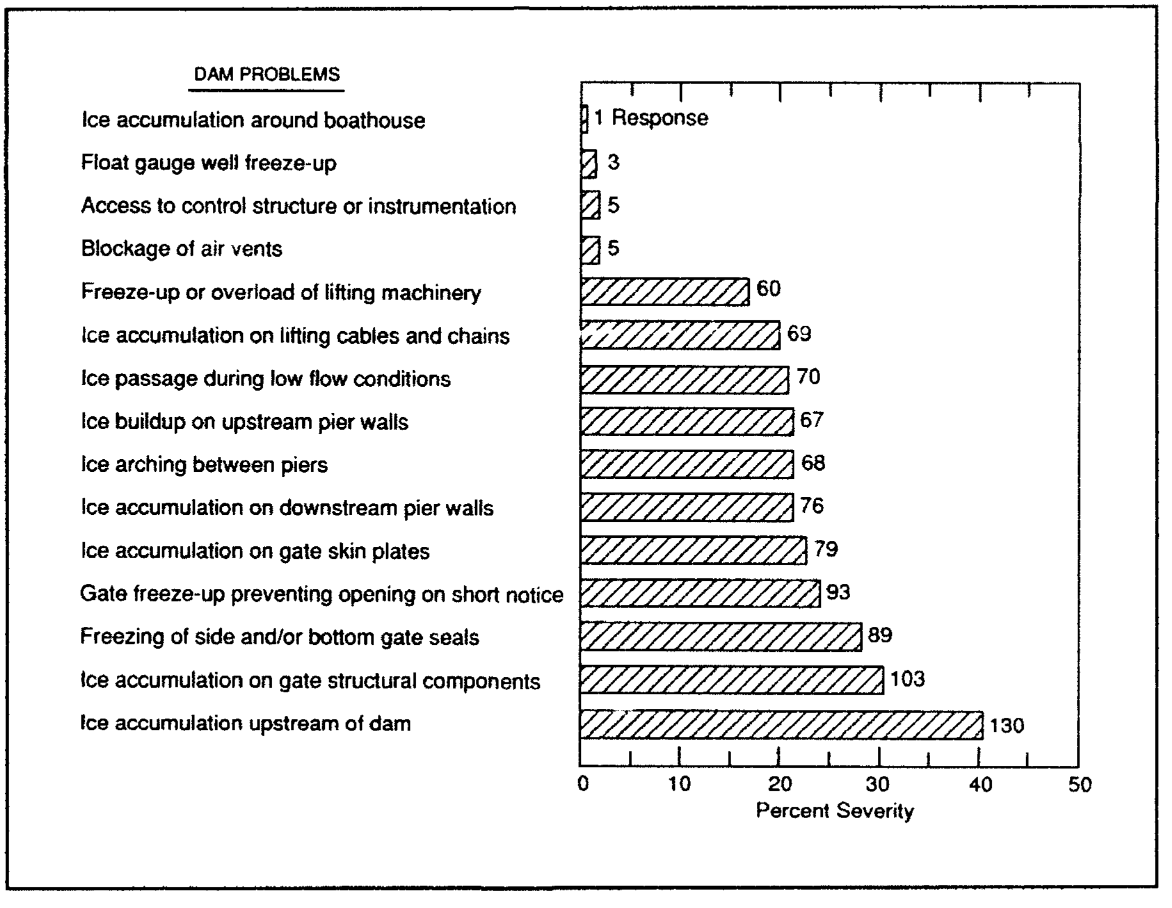

Figure 9. Severity of ice problems at dams

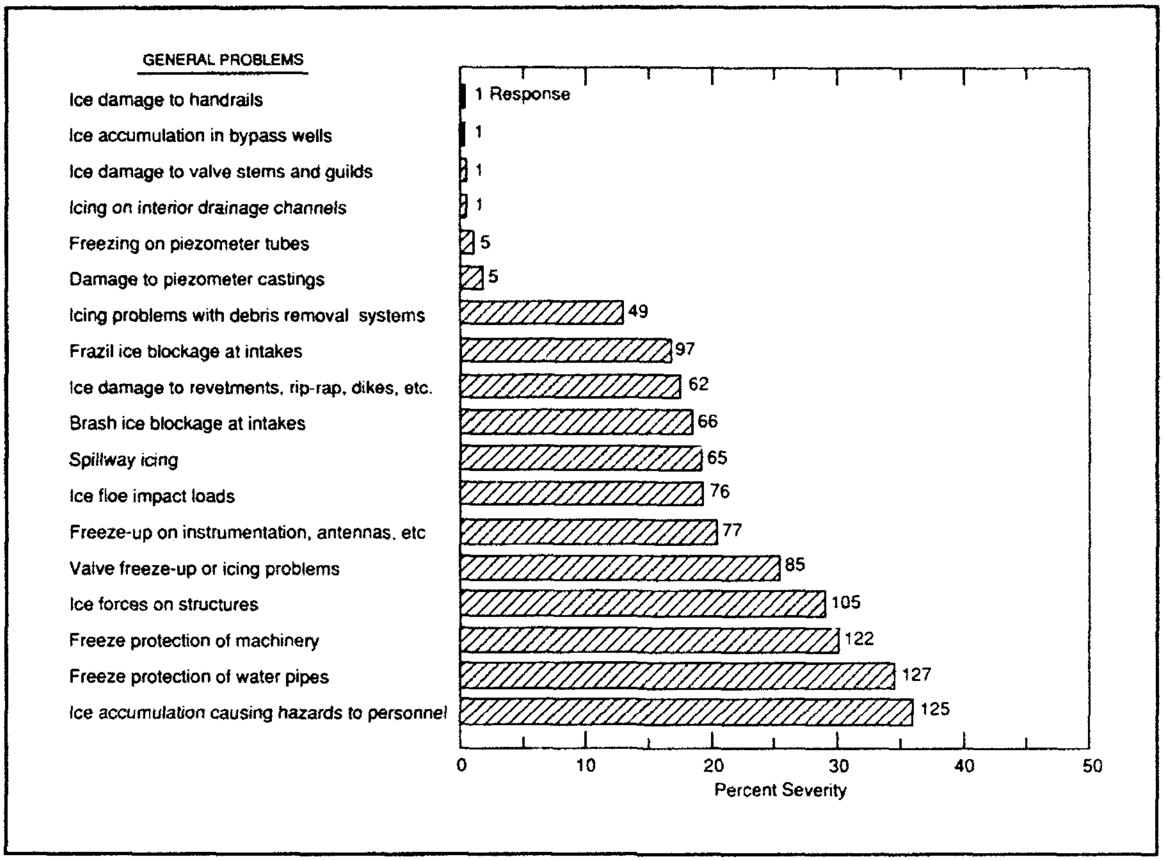

Figure 10. Severity of general ice problems

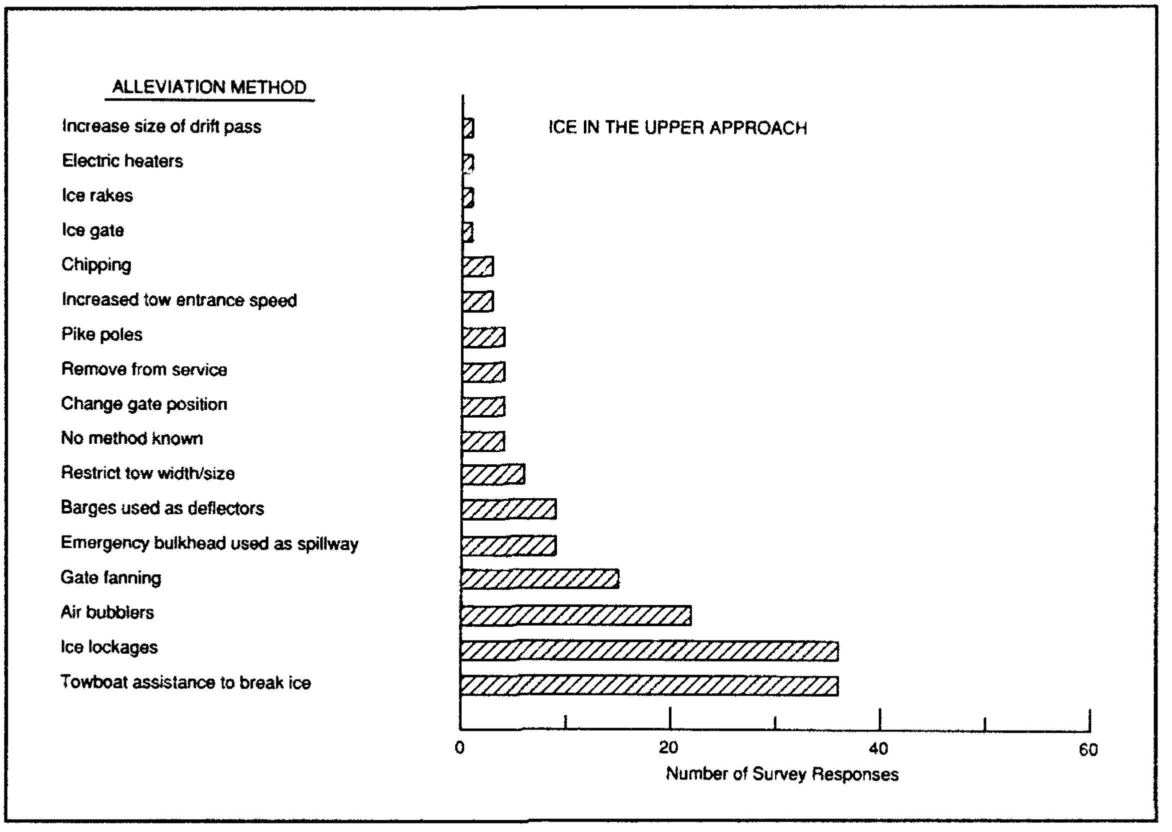

Figure 11. Ice in the upper approach, alleviation methods and number of responses

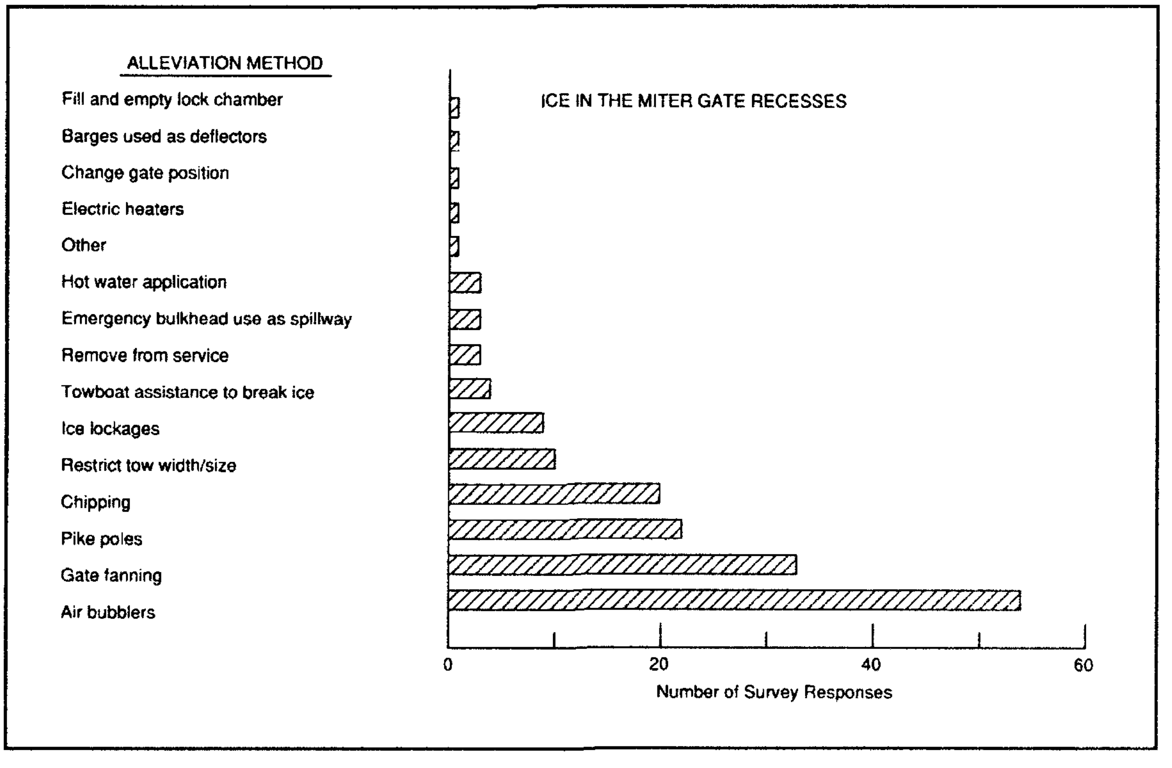

Figure 12. Ice in the miter gate recesses, alleviation methods and number of responses

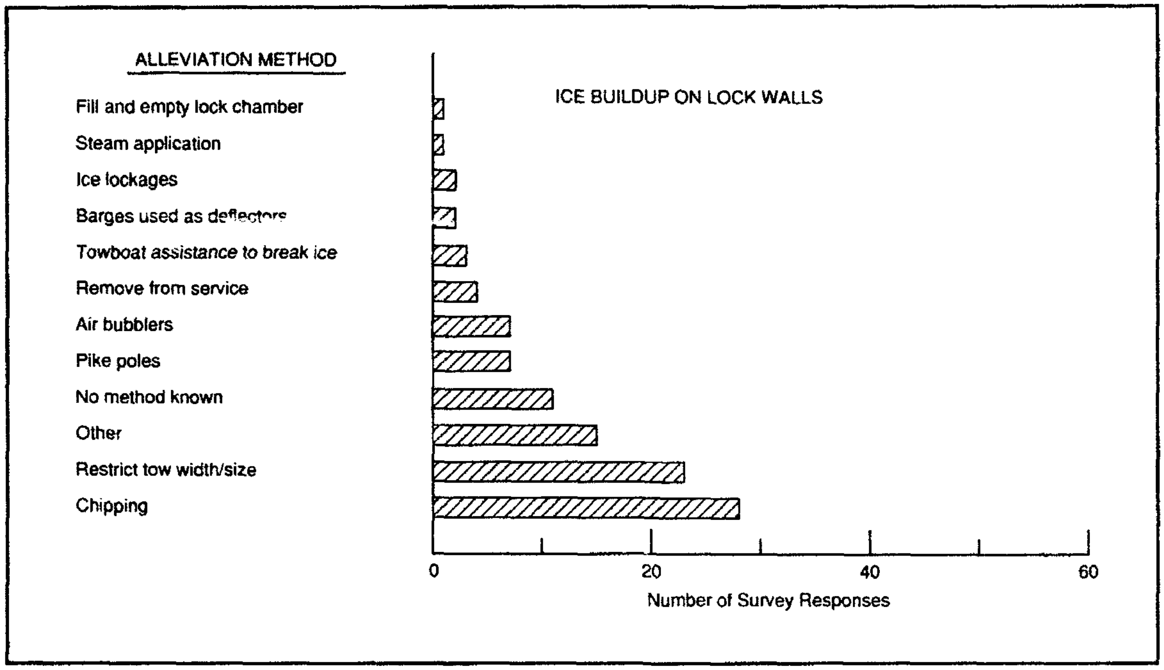

Figure 13. Ice buildup on lock walls, alleviation methods and number of responses

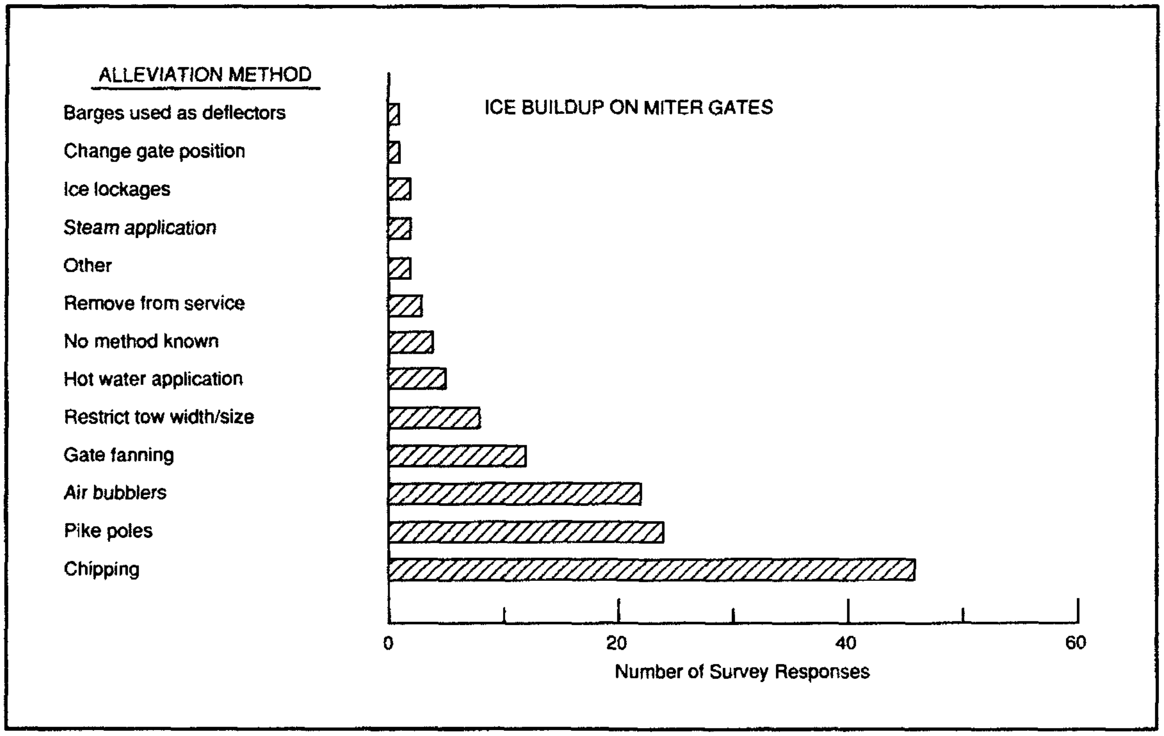

Figure 14. Ice buildup on miter gates, alleviation methods and number of responses

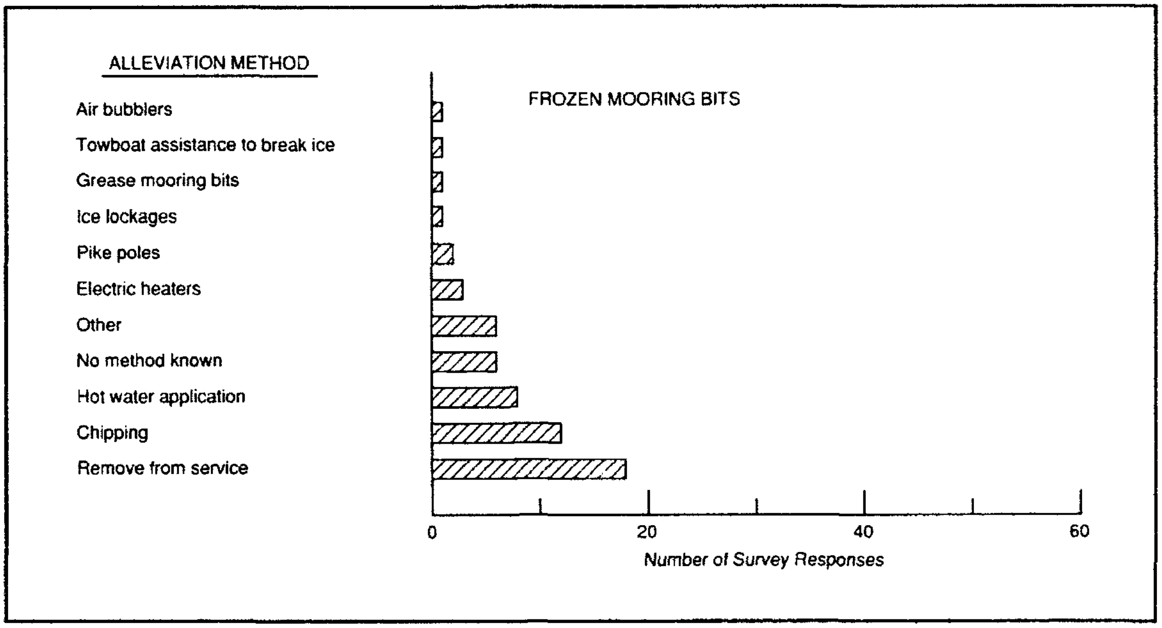

Figure 15. Frozen mooring bits, alleviation methods and number of responses

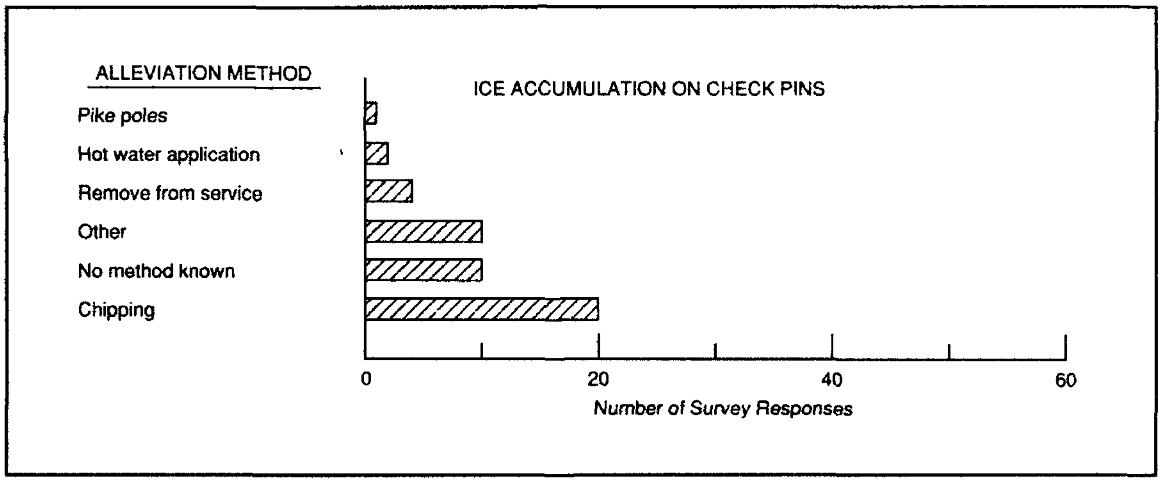

Figure 16. Ice accumulation on check pins, alleviation methods and number of responses

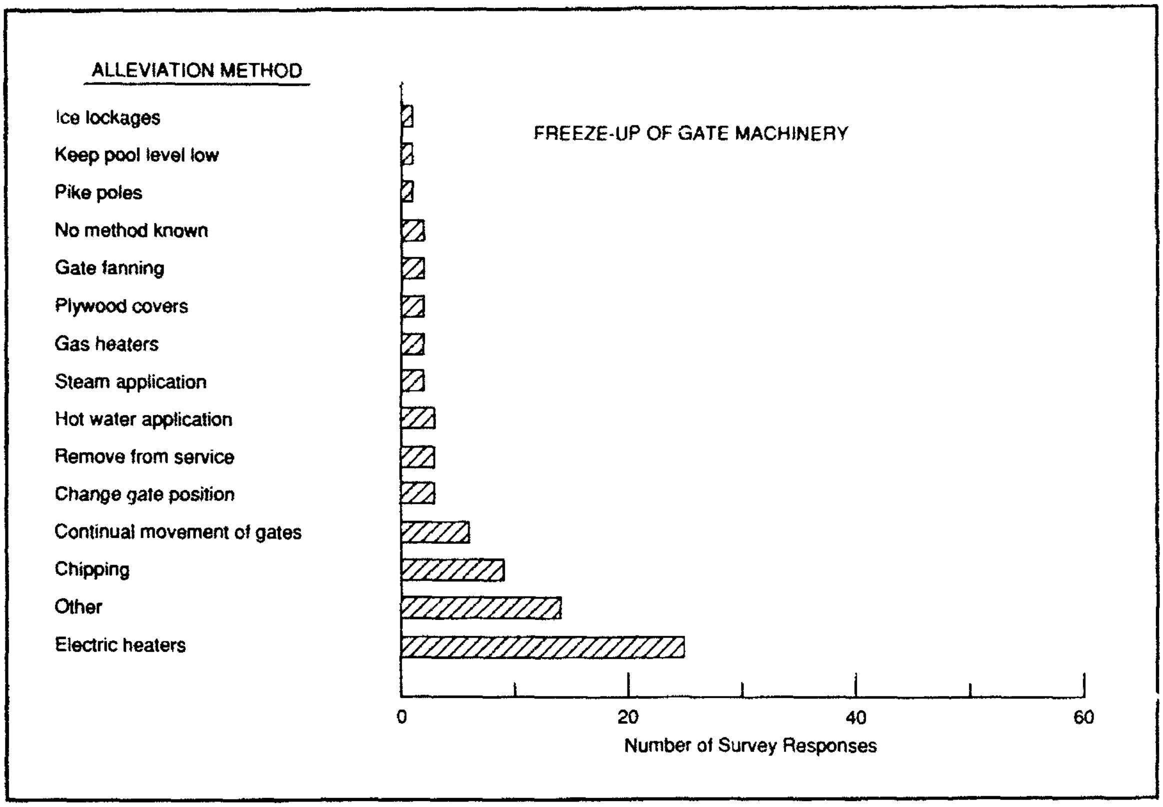

Figure 17. Freeze-up of gate machinery, alleviation methods and number of responses

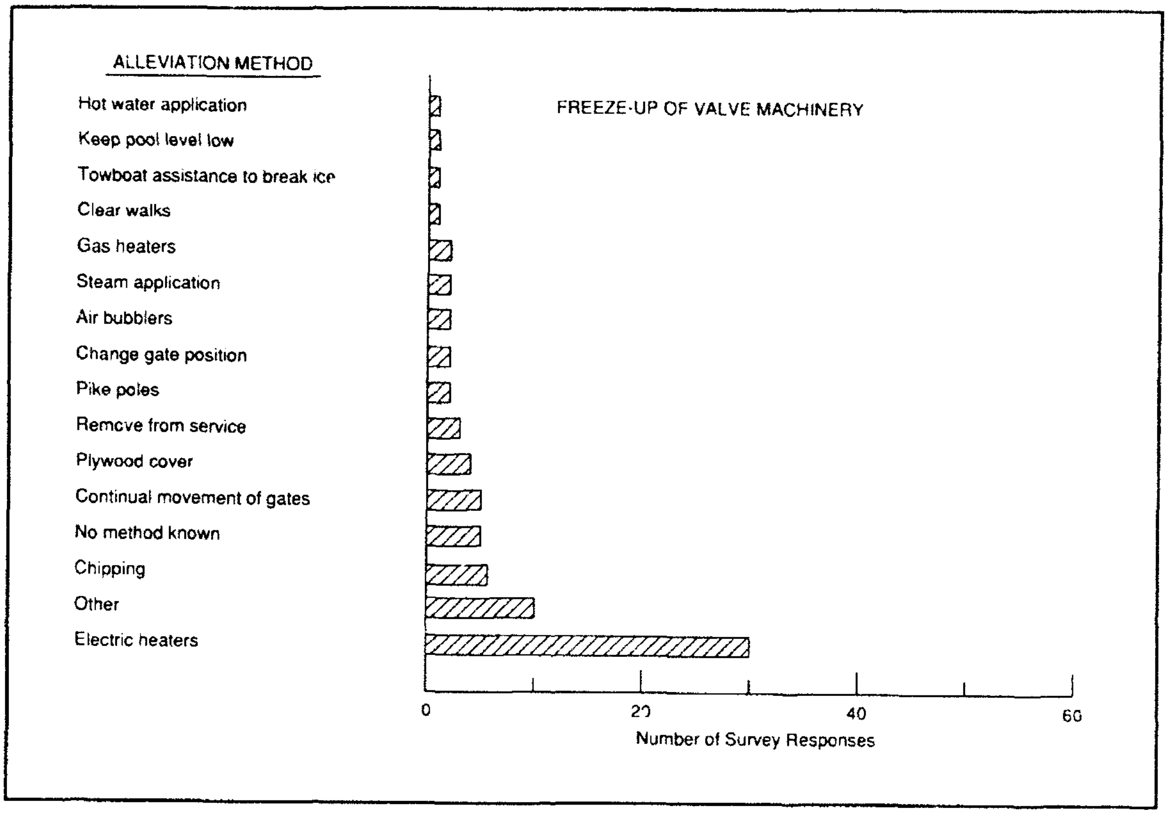

Figure 18. Freeze-up of valve machinery, alleviation methods and number of responses

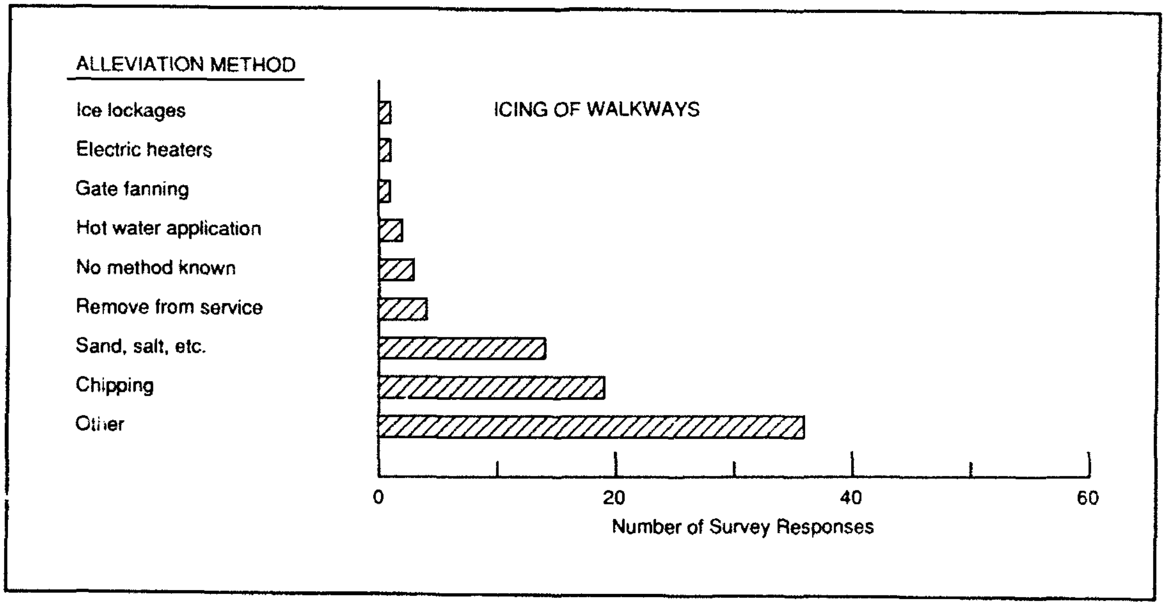

Figure 19. Icing of walkways, alleviation methods and number of responses

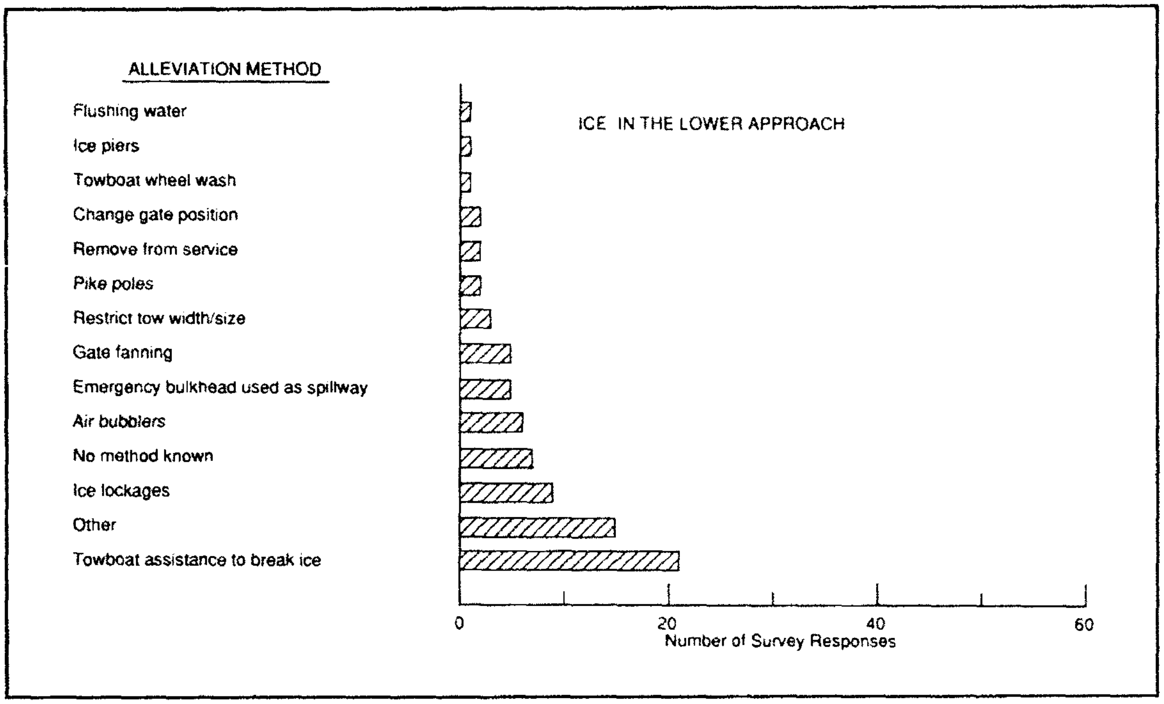

Figure 20. Ice in the lower approach, alleviation methods and number of responses

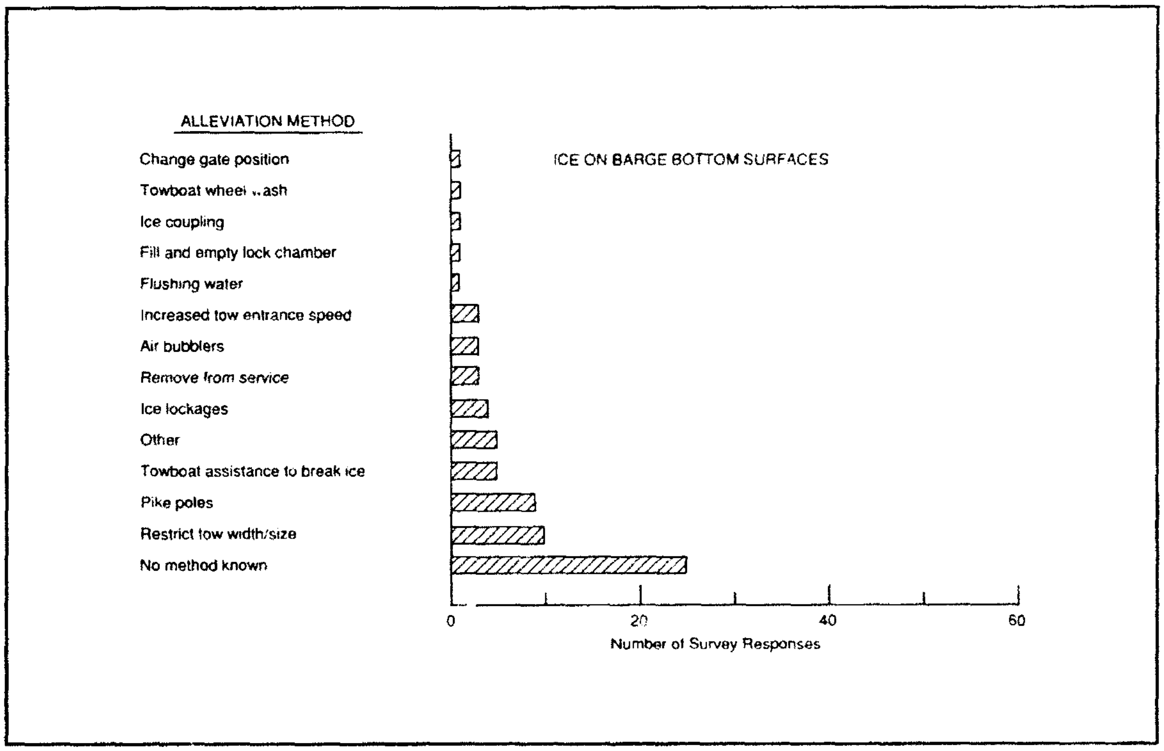

Figure 21. Ice o~ barge bottom surfaces, alleviation methods and number of responses

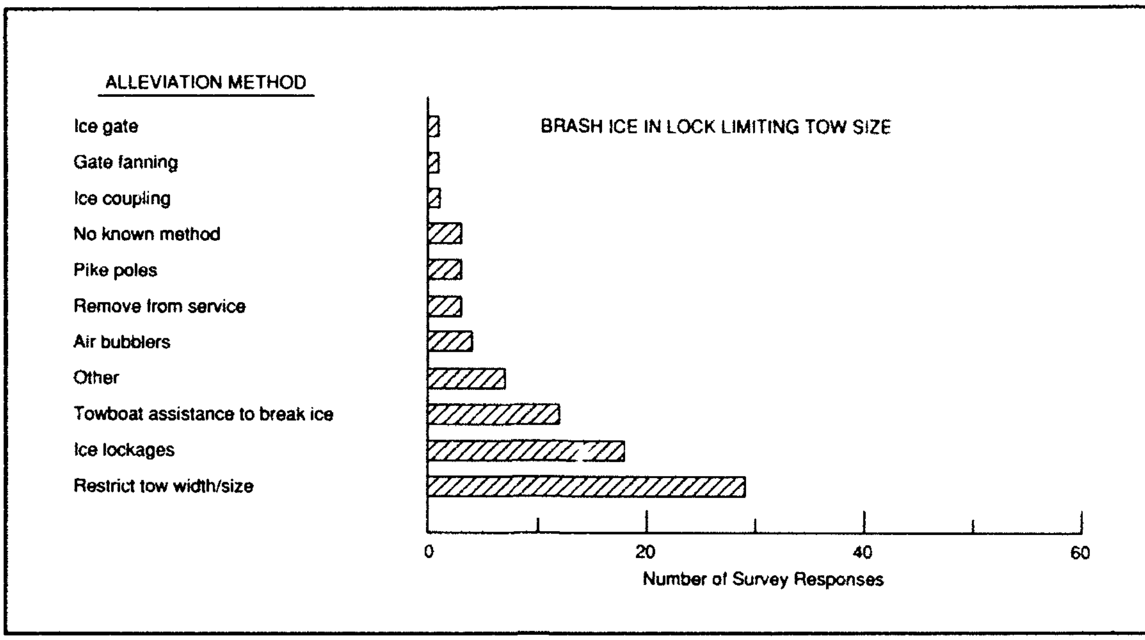

Figure 22. Brash ice in lock limiting tow size, alleviation methods and number of responses

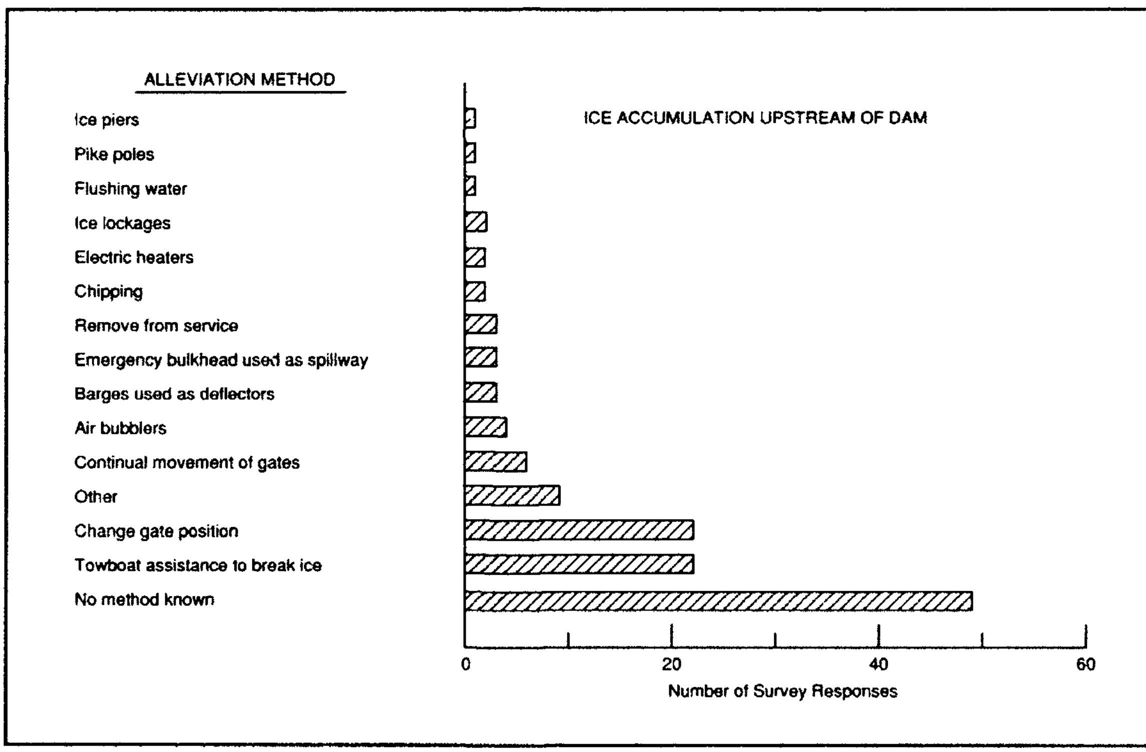

Figure 23. Ice accumulation upstream of dam, alleviation methods and number of responses

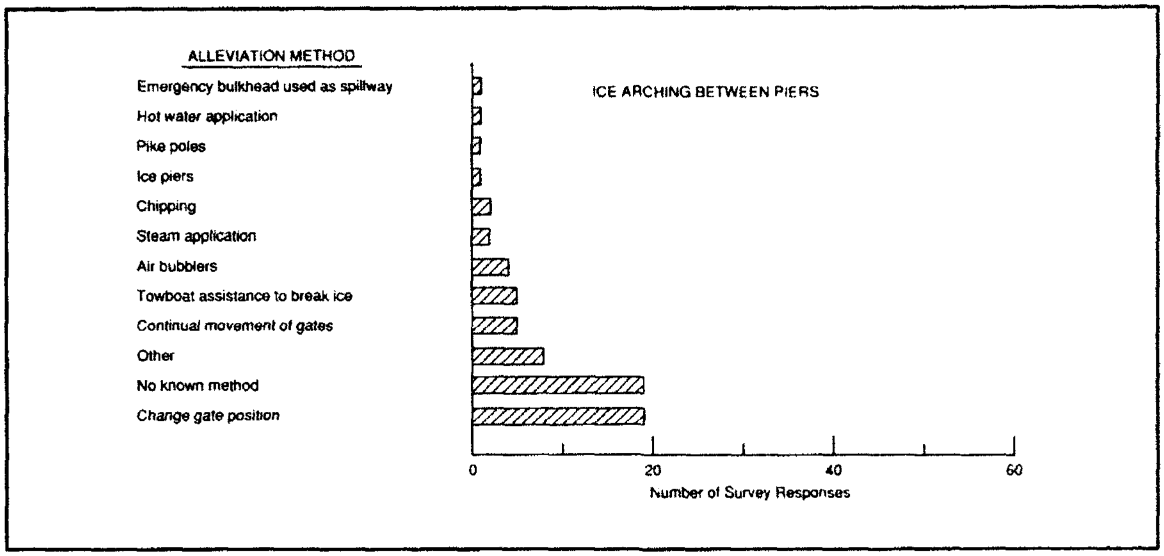

Figure 24. Ice arching between piers, alleviation methods and number of responses

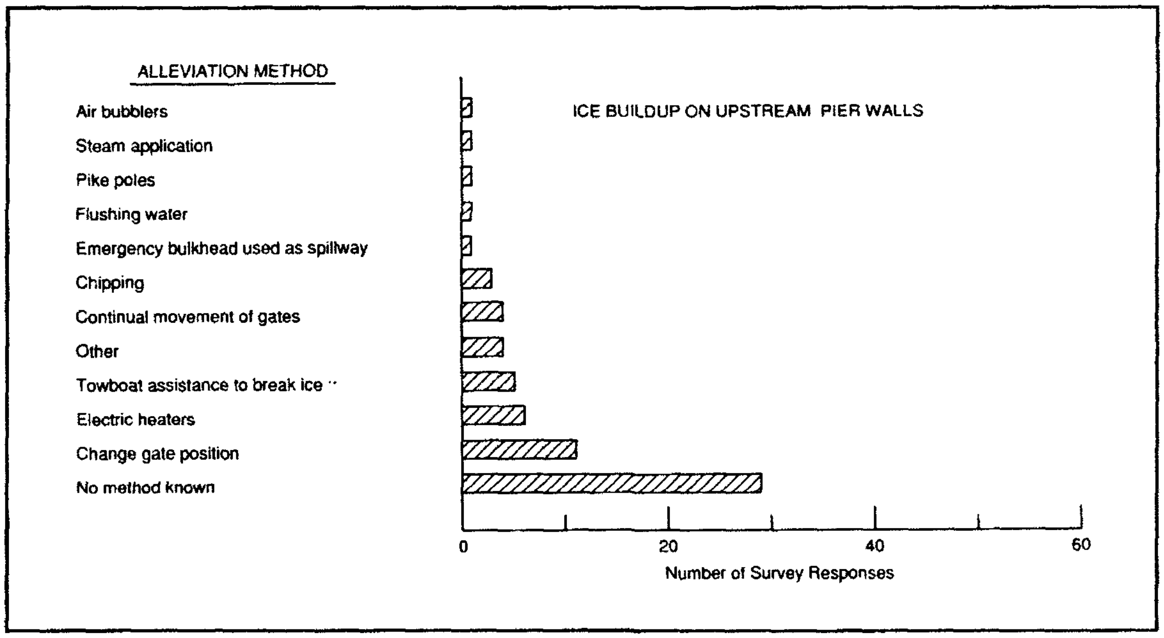

Figure 25. Ice buildup on upstream pier walls, alleviation methods and number of responses

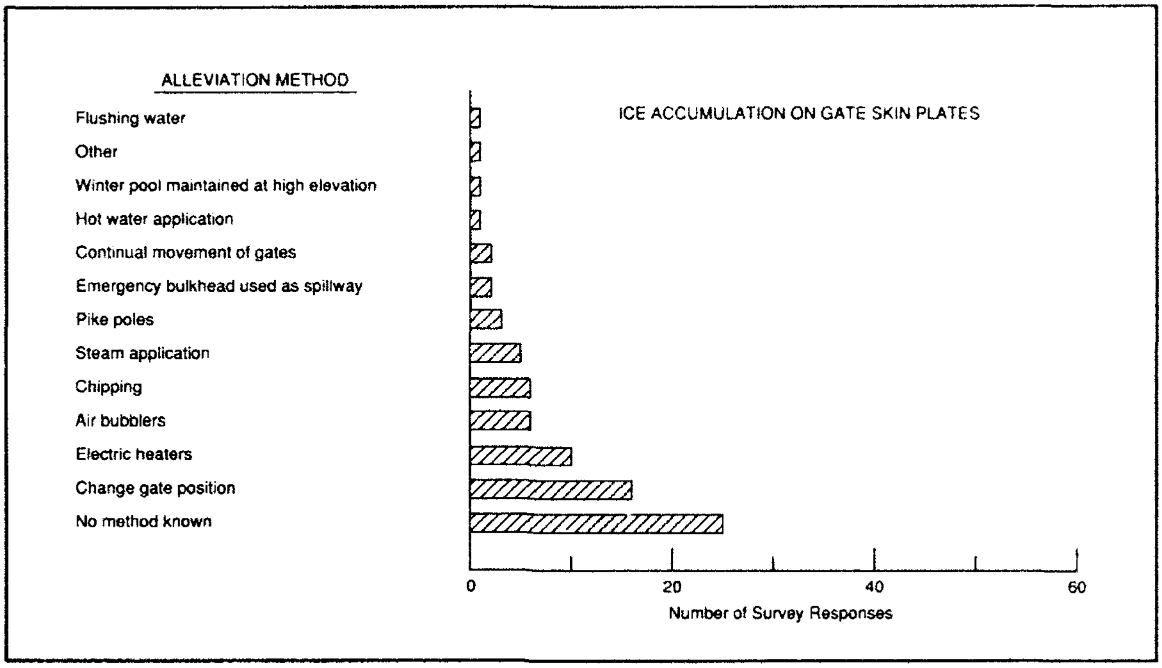

Figure 26. Ice accumulation on gate skin plate, alleviation methods and number of responses

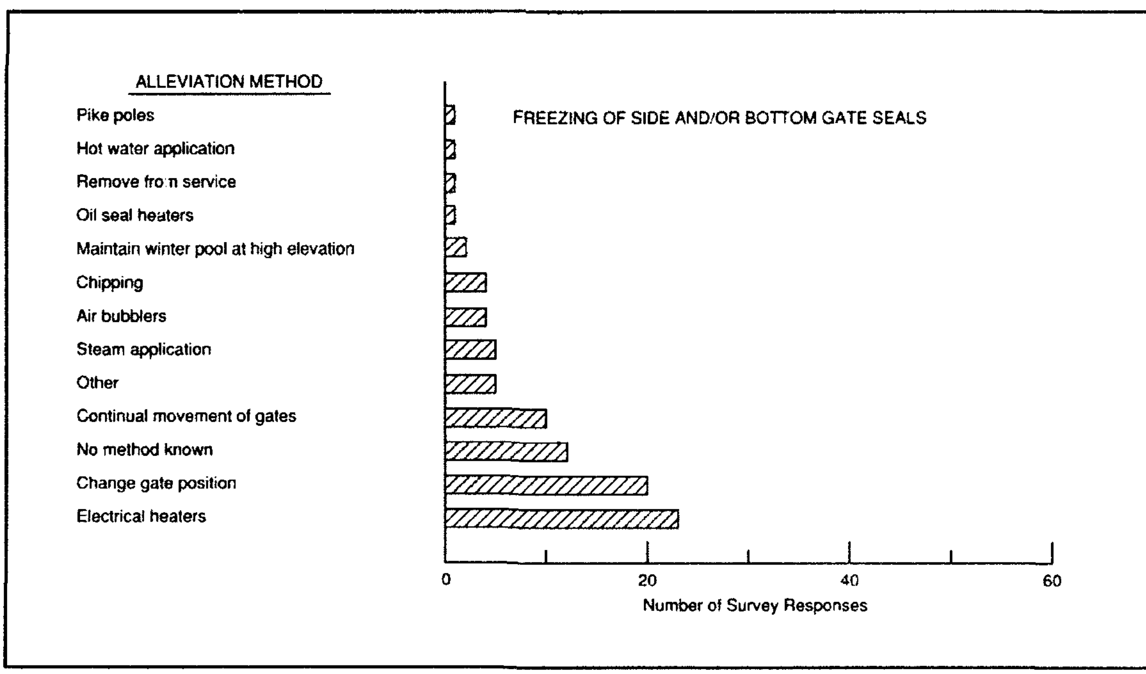

Figure 27. Freezing of side and/or bottom gate seals, alleviation methods and number of responses

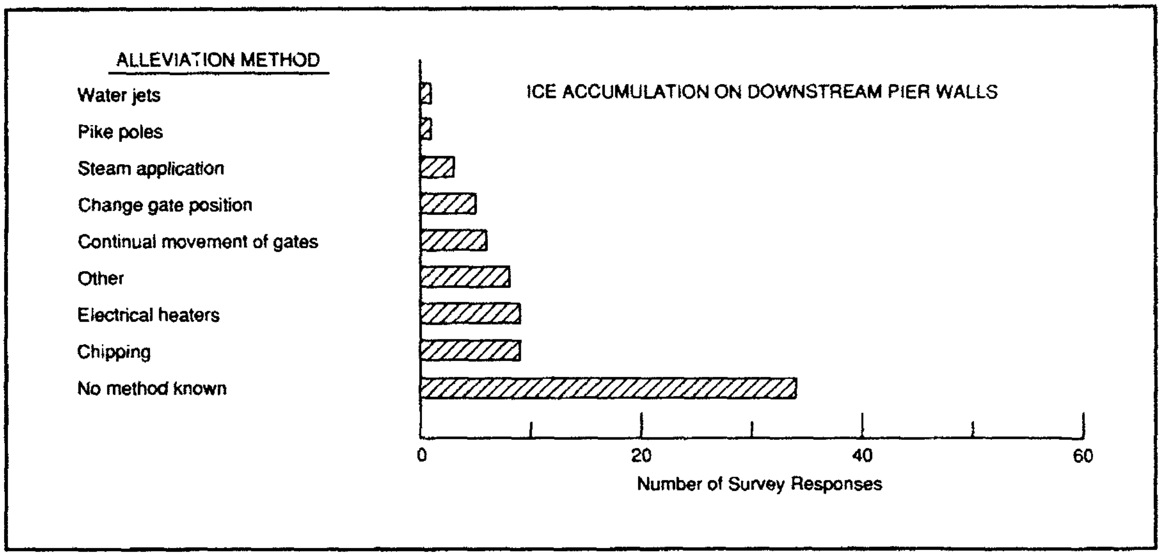

Figure 28. Ice accumulation on downstream pier walls, alleviation methods and number of responses

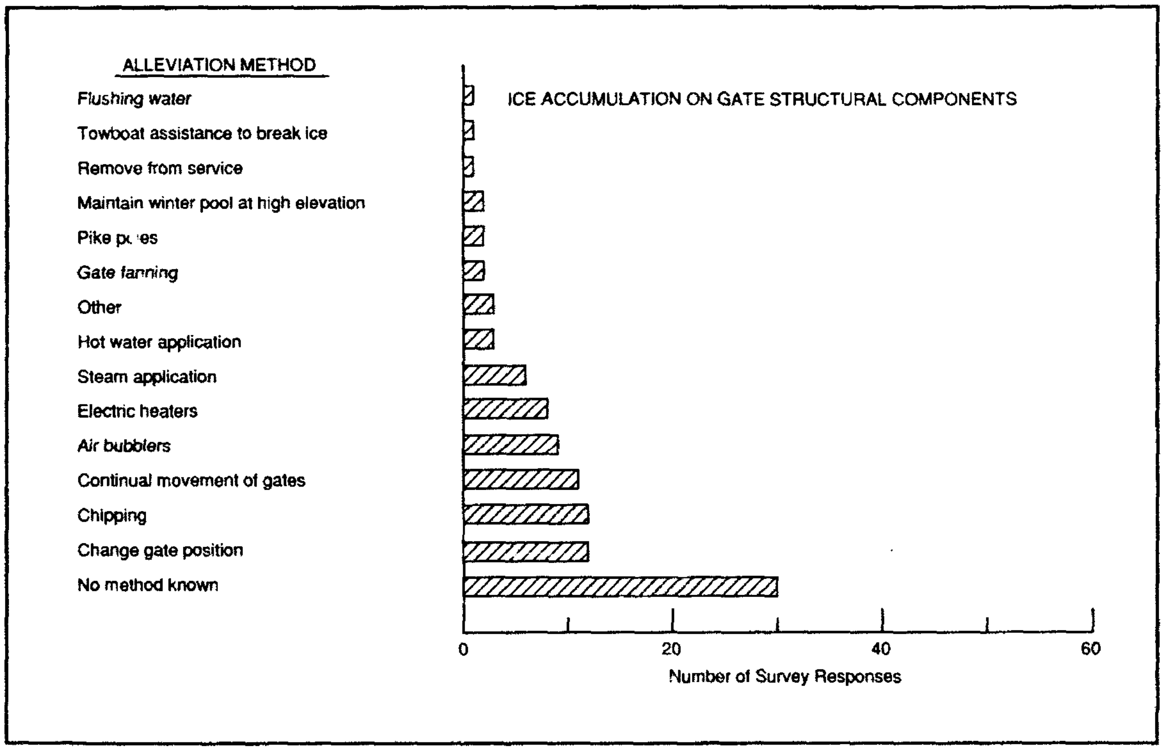

Figure 29. Ice accumulation on gate structural components, alleviation methods and number of responses

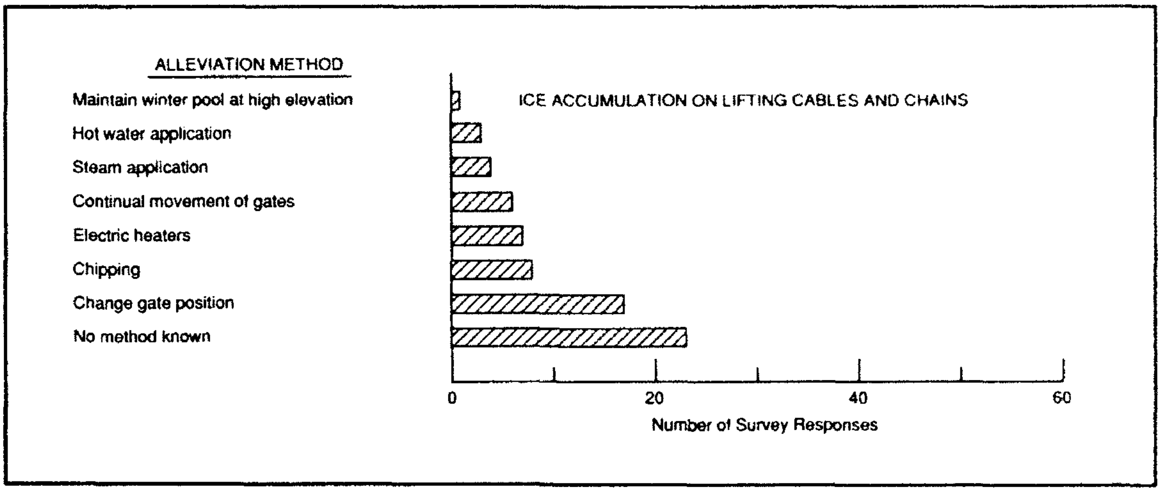

Figure 30. Ice accumulation on lifting cables and chains, alleviation methods and number of responses

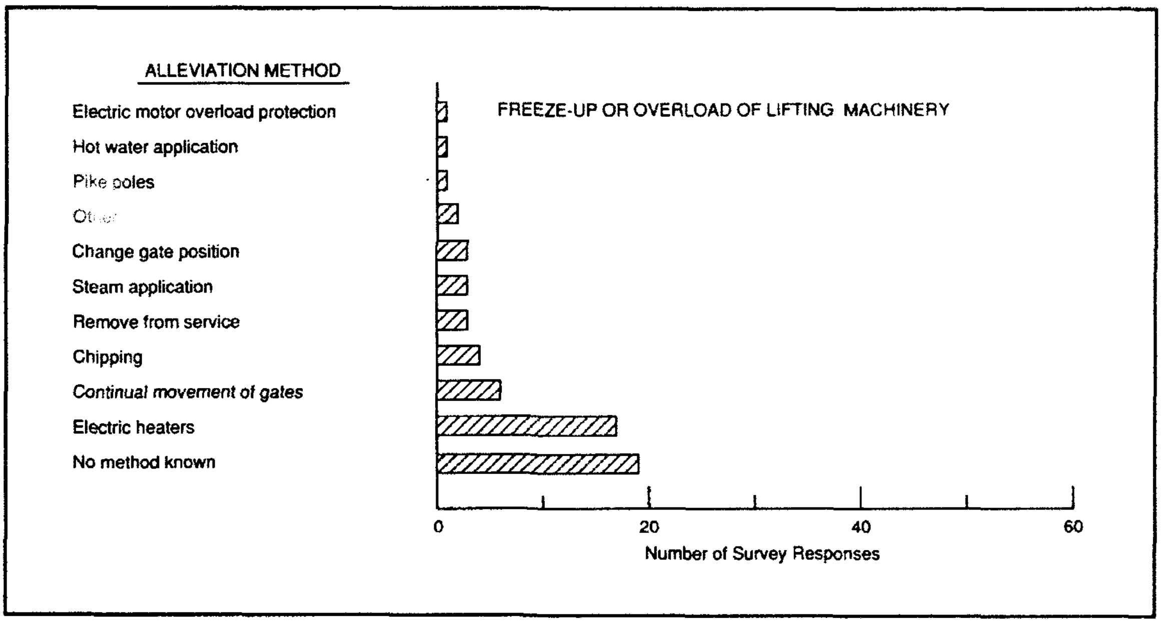

Figure 31. Freeze-up or overload of lifting machinery, alleviation methods and number of responses

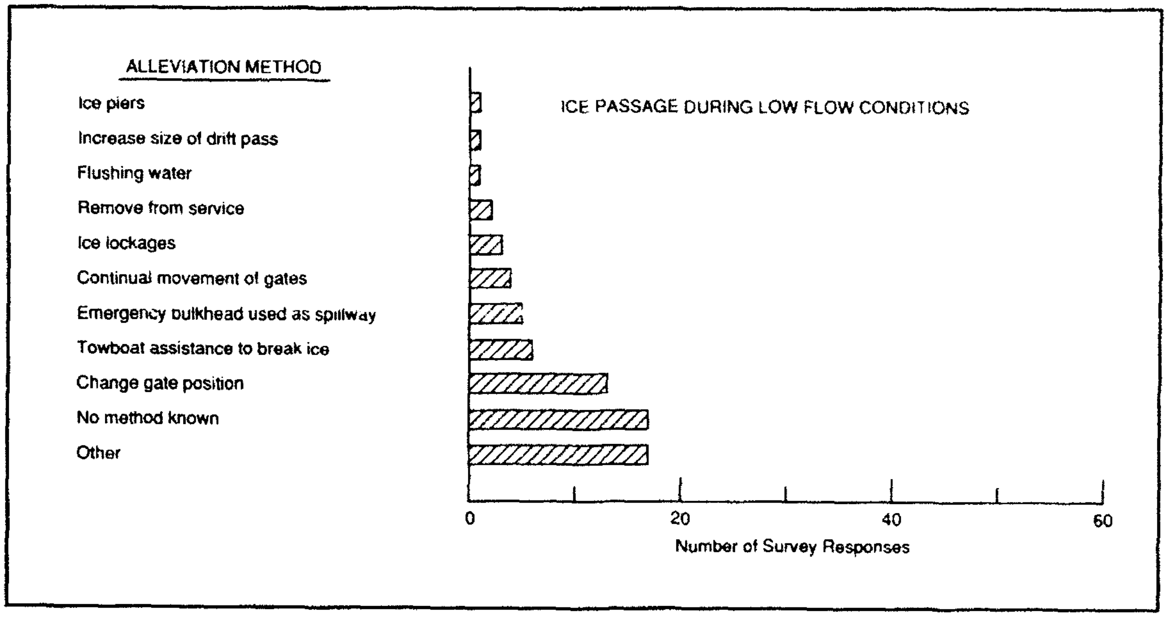

Figure 32. Ice passage during low flow conditions, alleviation methods and number of responses

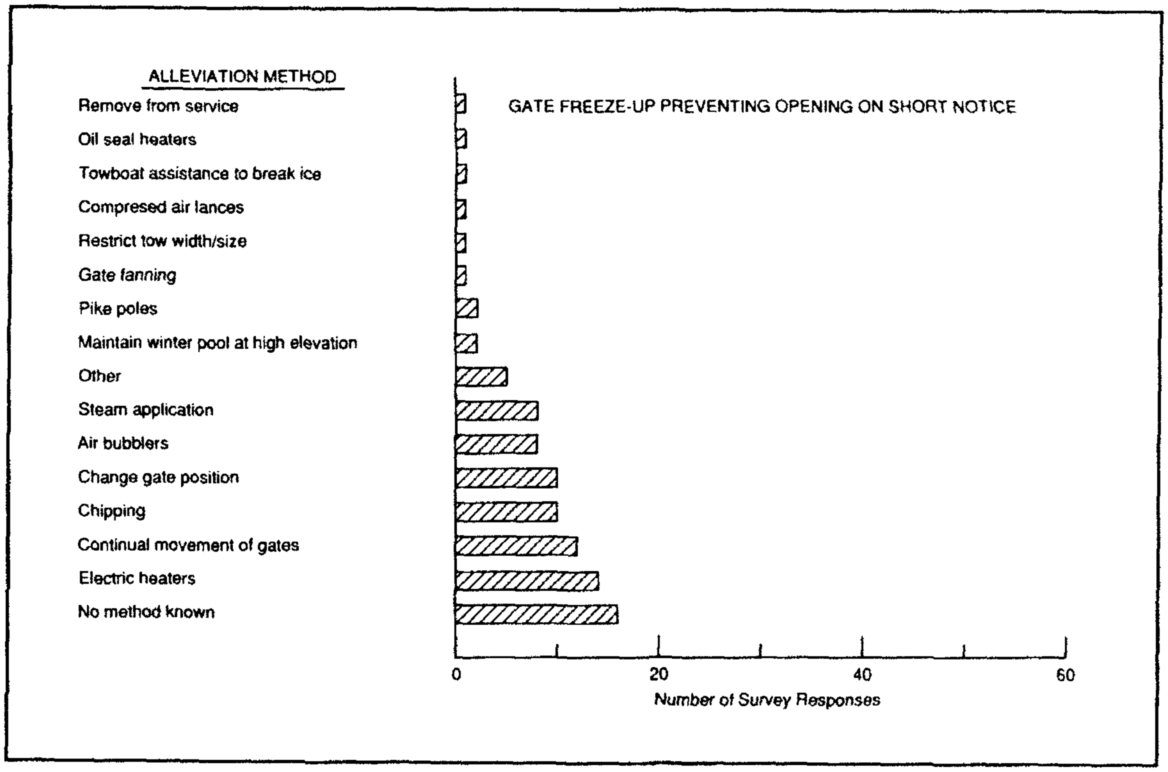

Figure 33. Gate freeze-up preventing opening on short notice, alleviation methods and number of responses

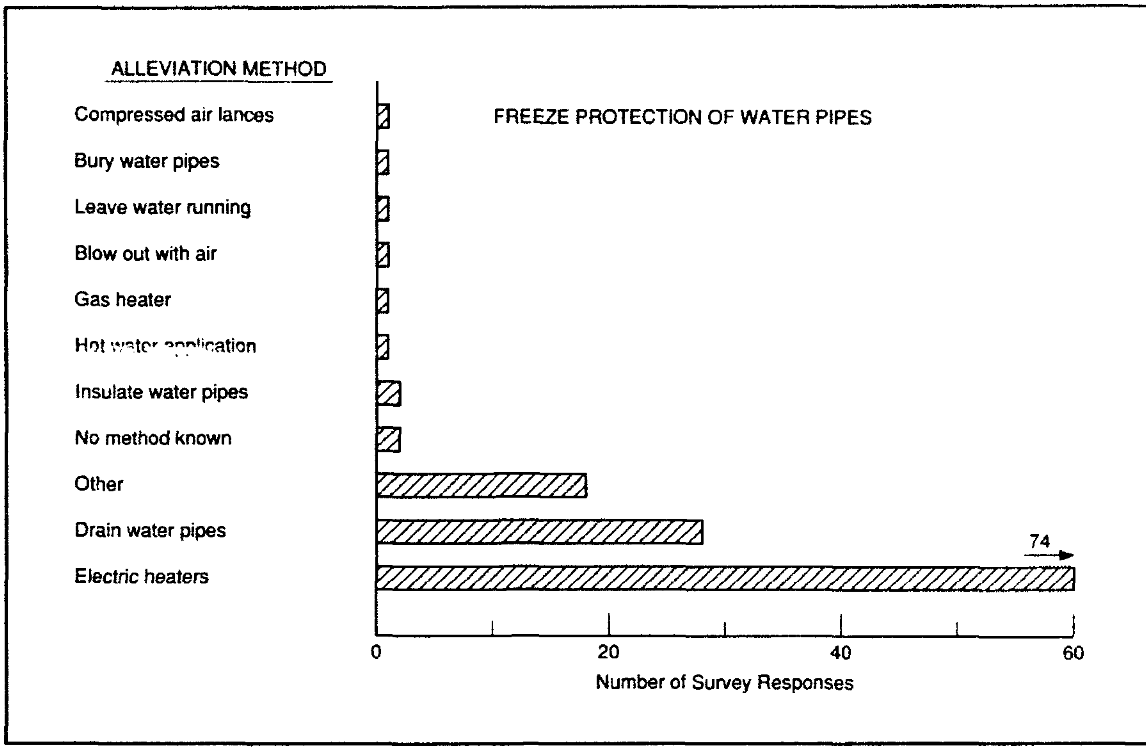

Figure 34. Freeze protection of water pipes, alleviation methods and number of responses

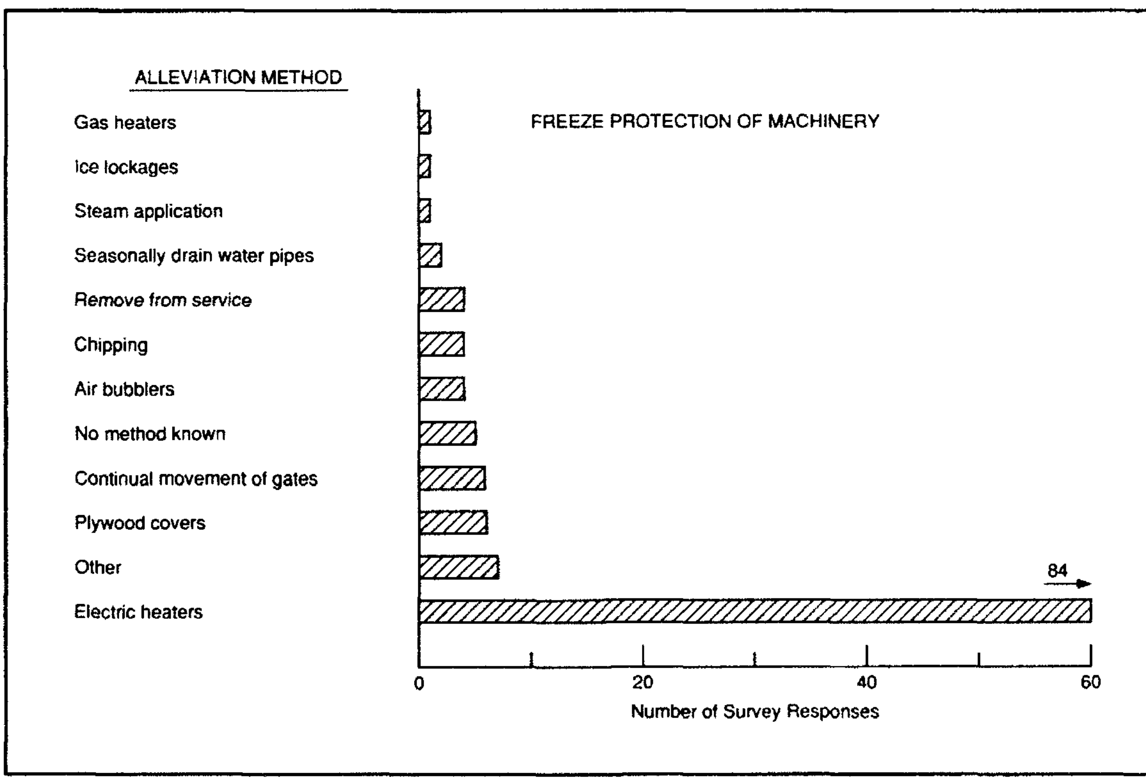

Figure 35. Freeze protection of machinery, alleviation methods and number of responses

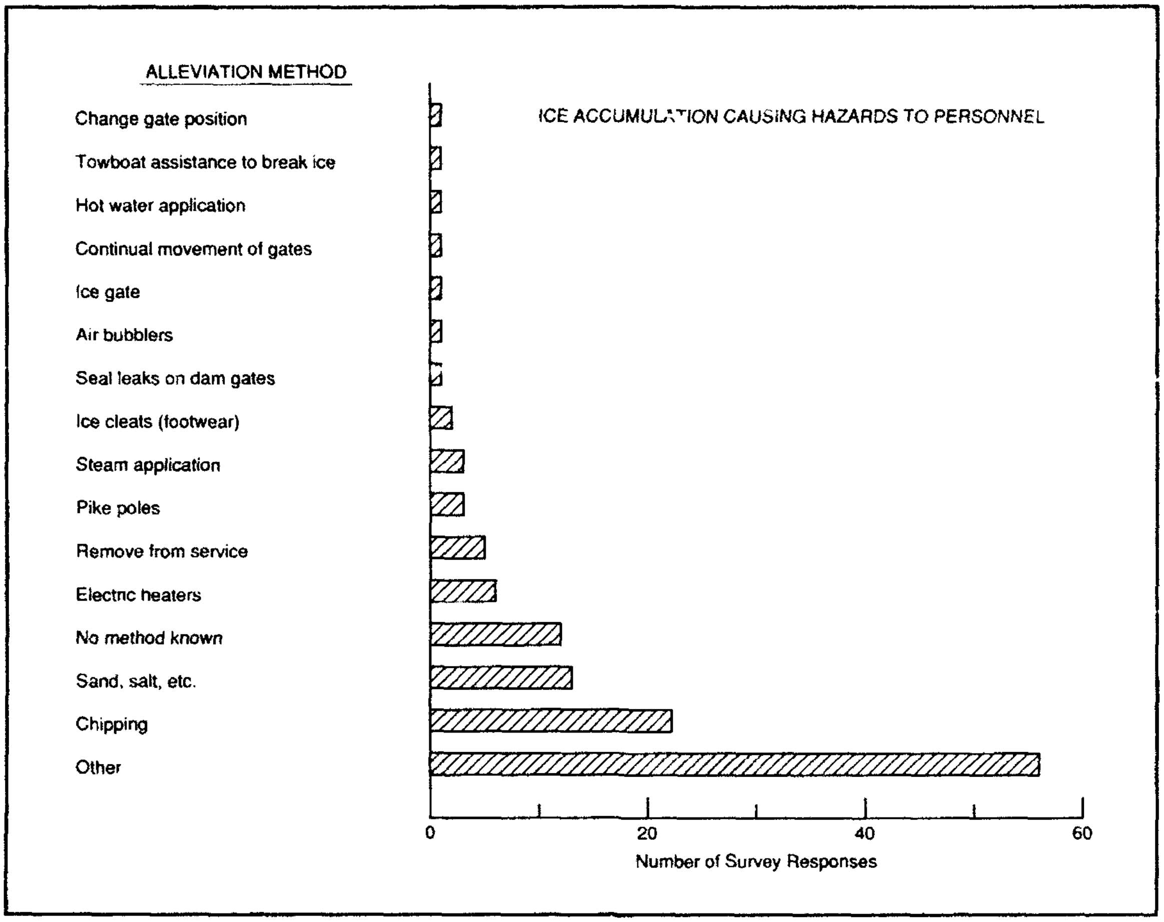

Figure 36. Ice accumulation causing hazards to personnel, alleviation methods and number of responses

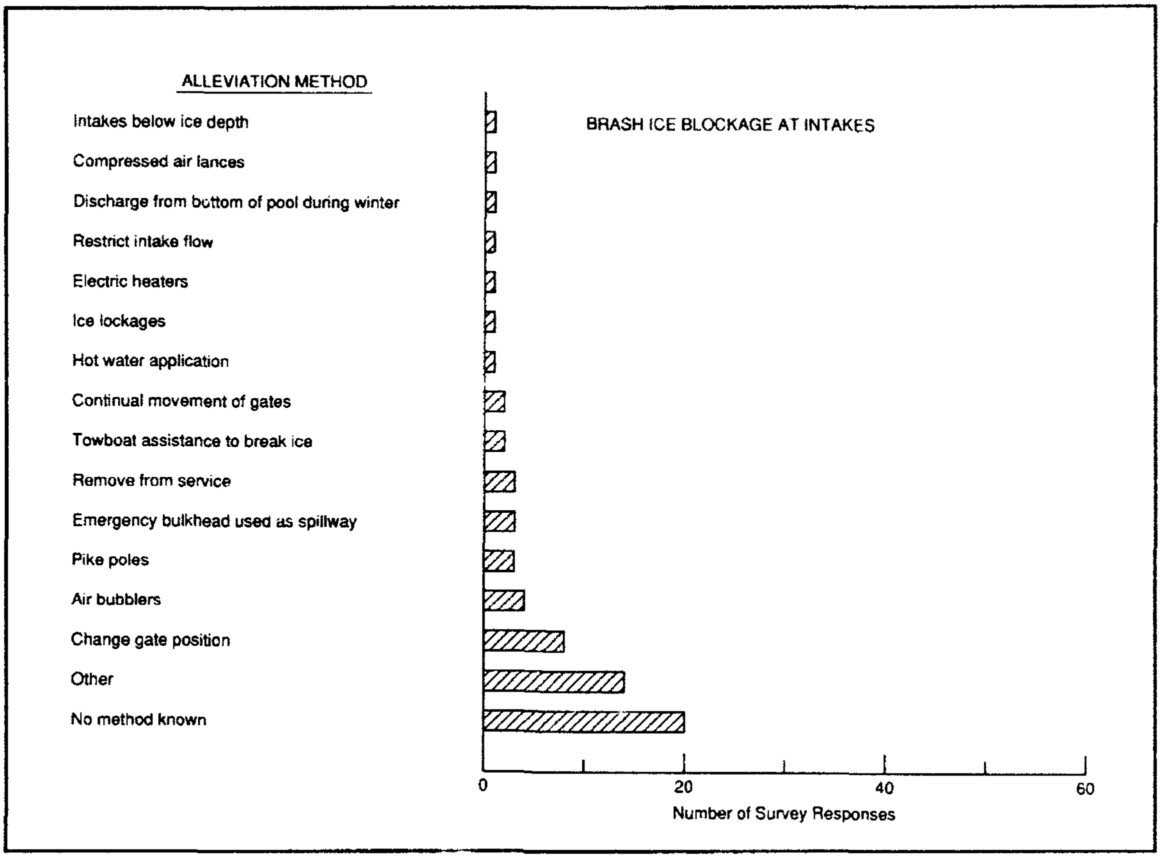

Figure 37. Brash ice blockage at intakes, alleviation methods and number of responses

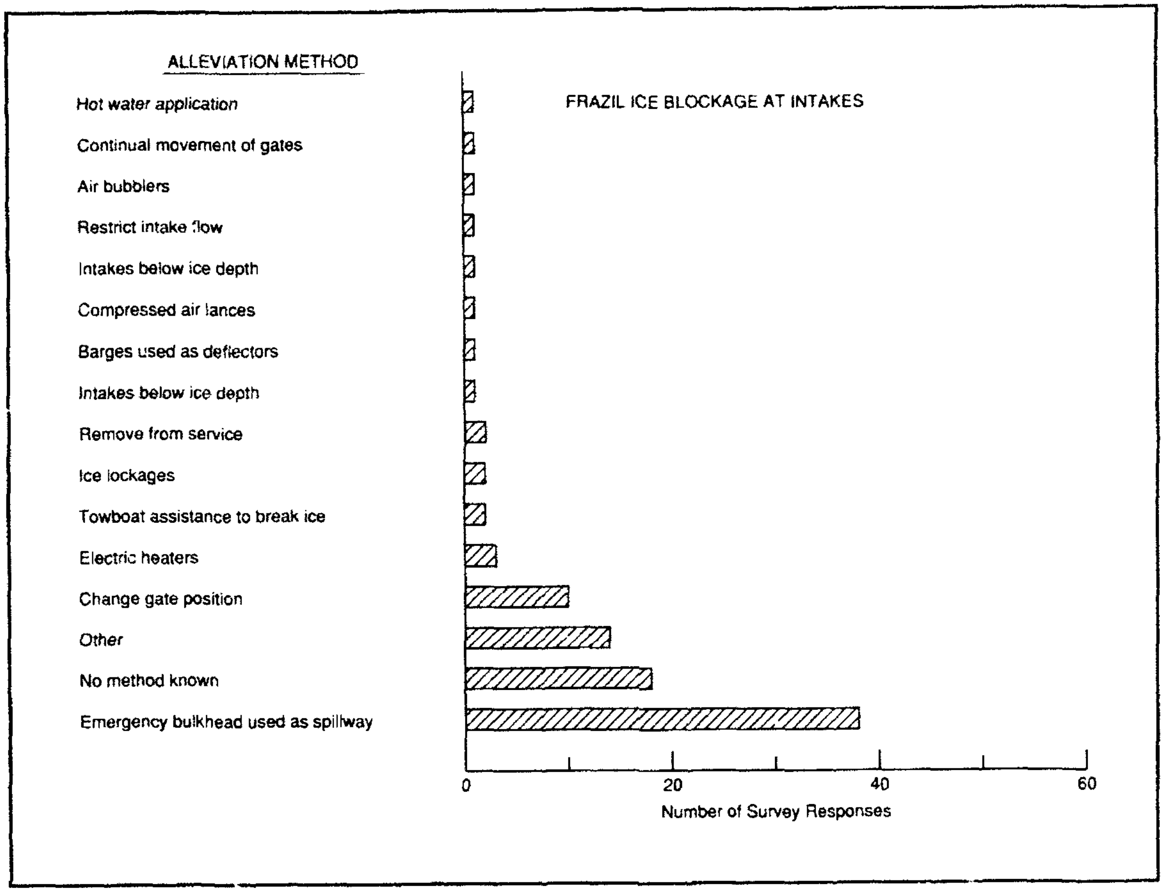

Figure 38. Frazil blockage at intakes, alleviation methods and number of responses

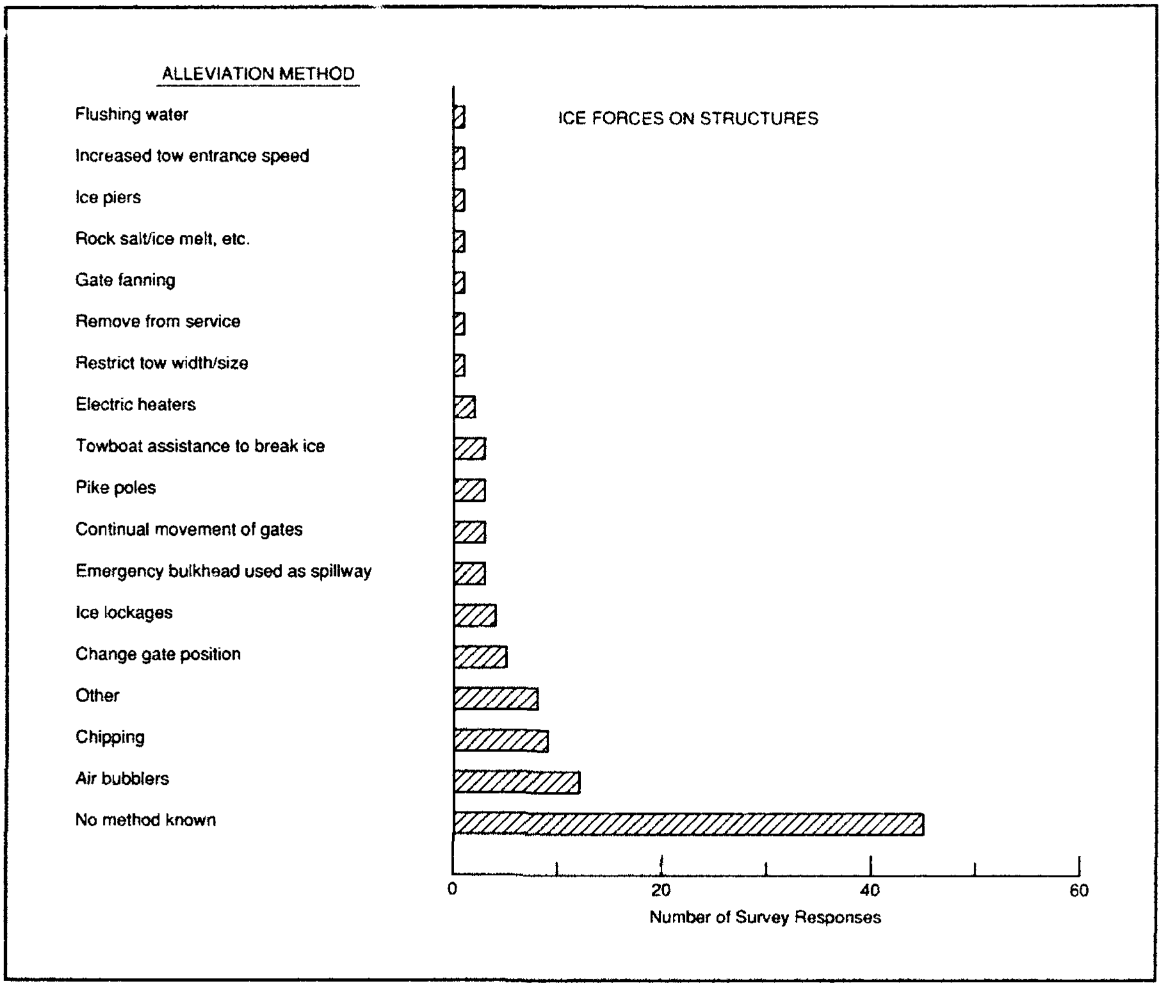

Figure 39. Ice forces on structures, alleviation methods and number of responses

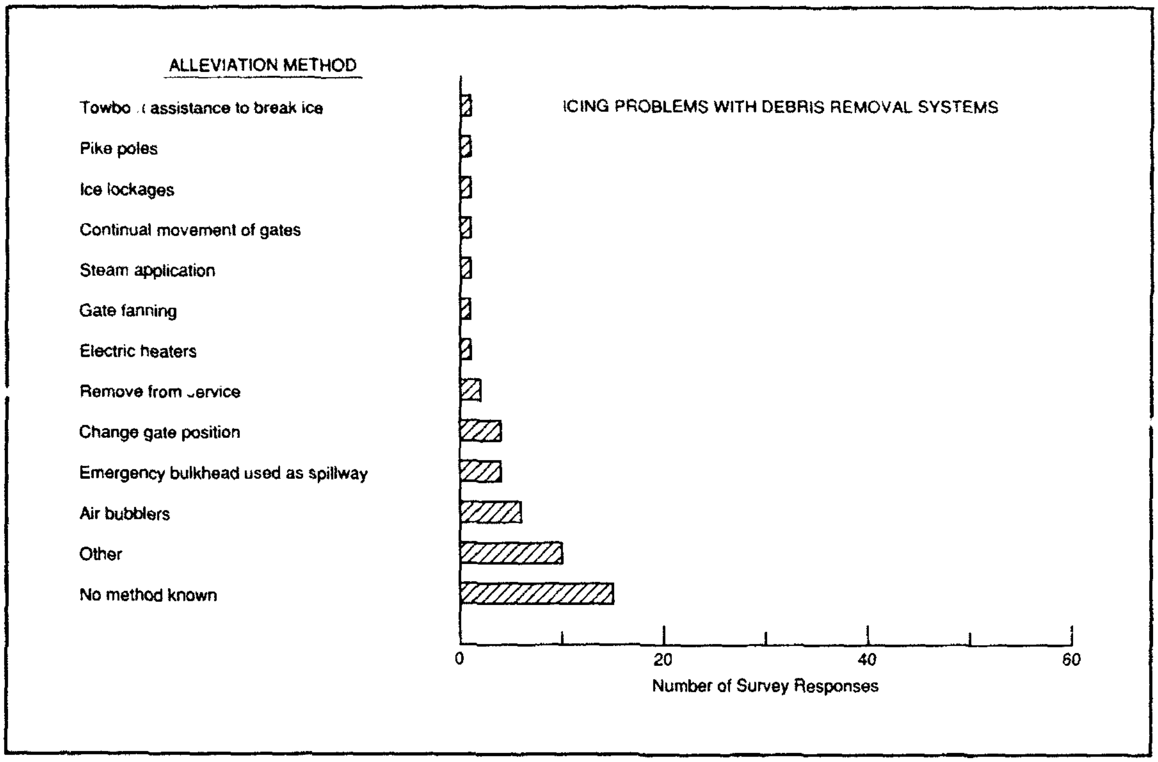

Figure 40. Icing problems with debris removal systems, alleviation methods and number of responses

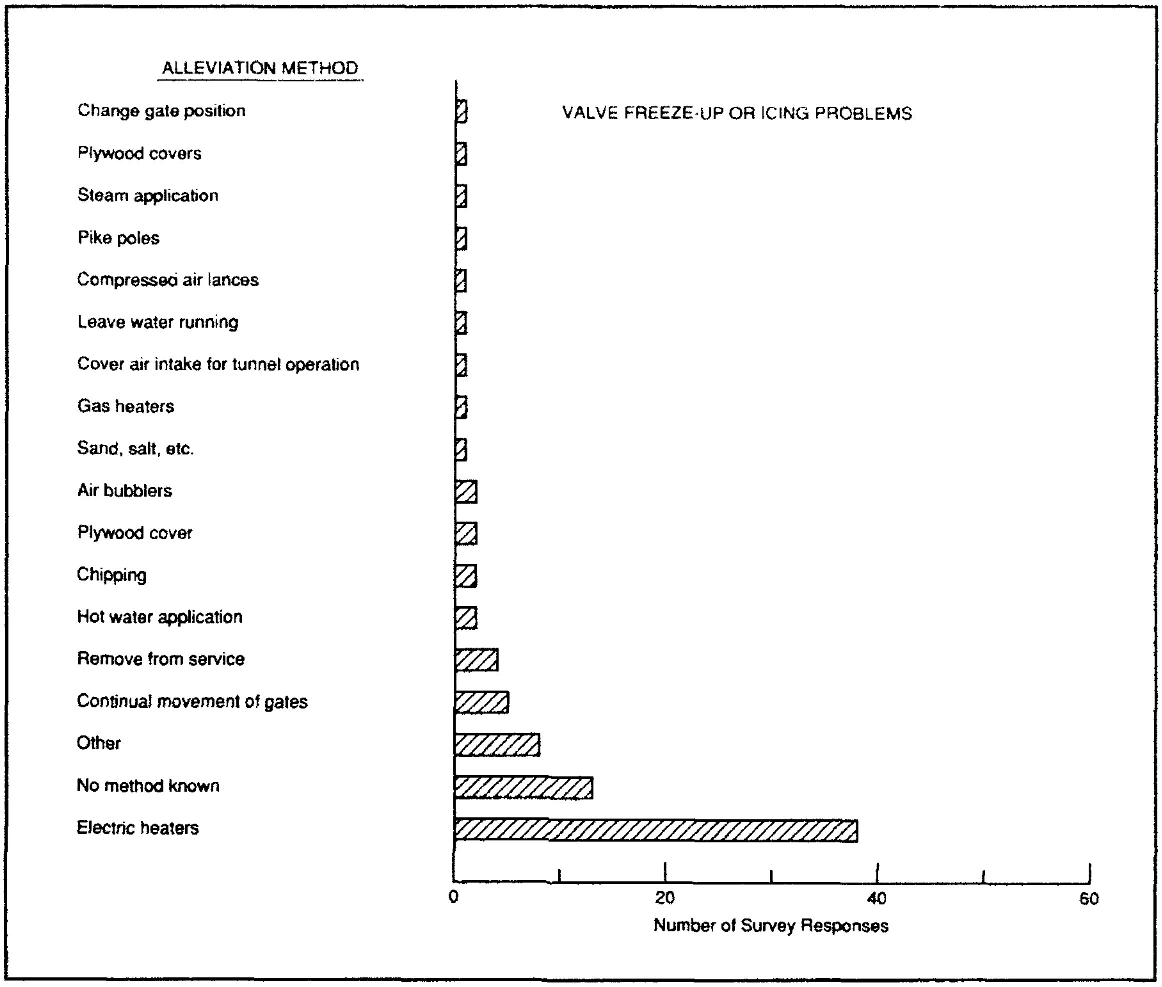

Figure 41. Valve freeze-up or icing problems, alleviation methods and number of responses

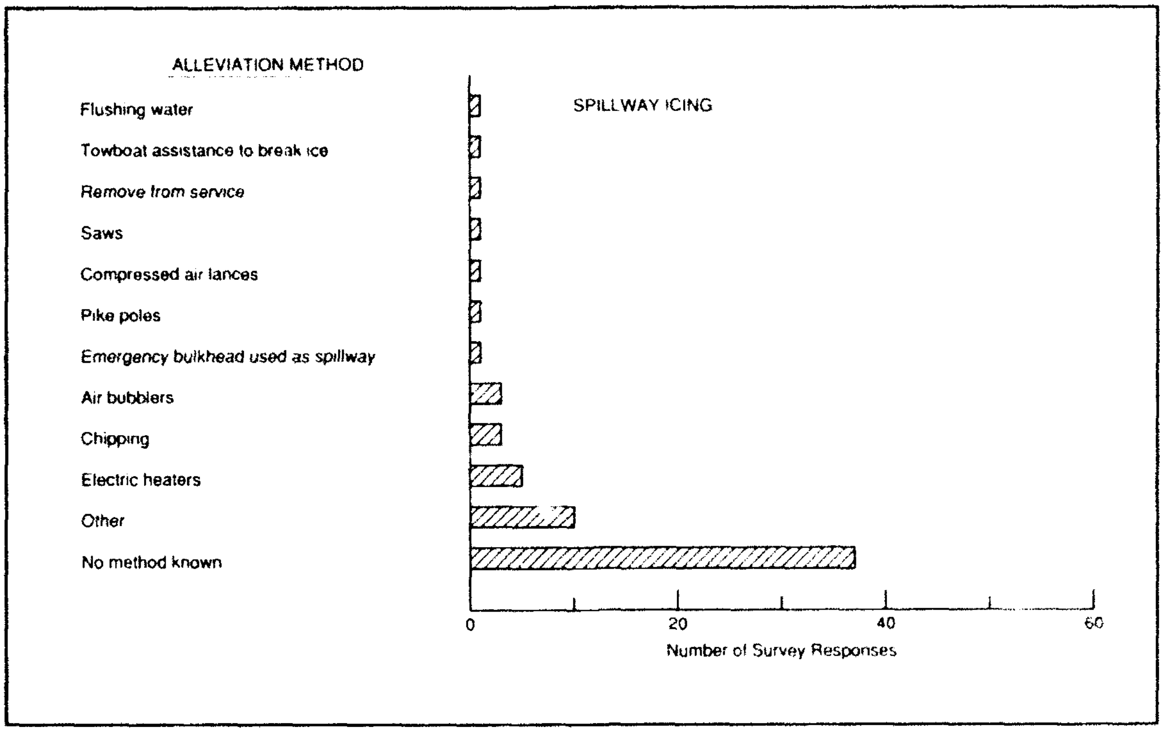

Figure 42. Spillway icing, alleviation methods and number of responses

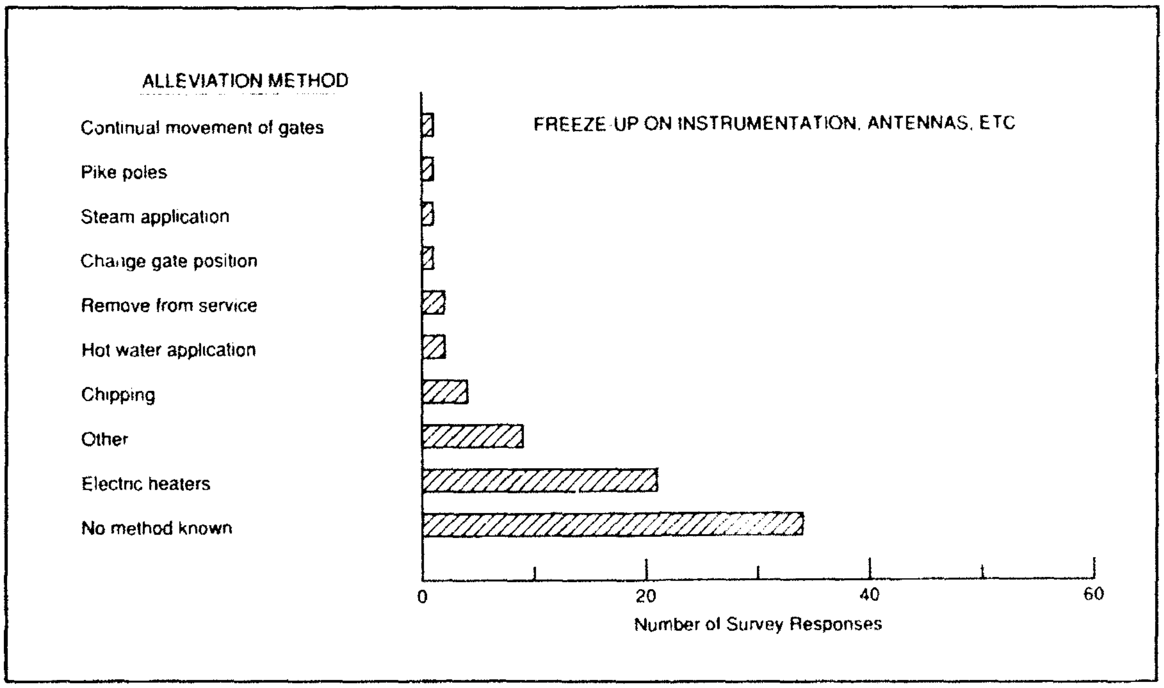

Figure 43. Freeze-up on instrumentation, antennas, etc., alleviation methods and number of responses

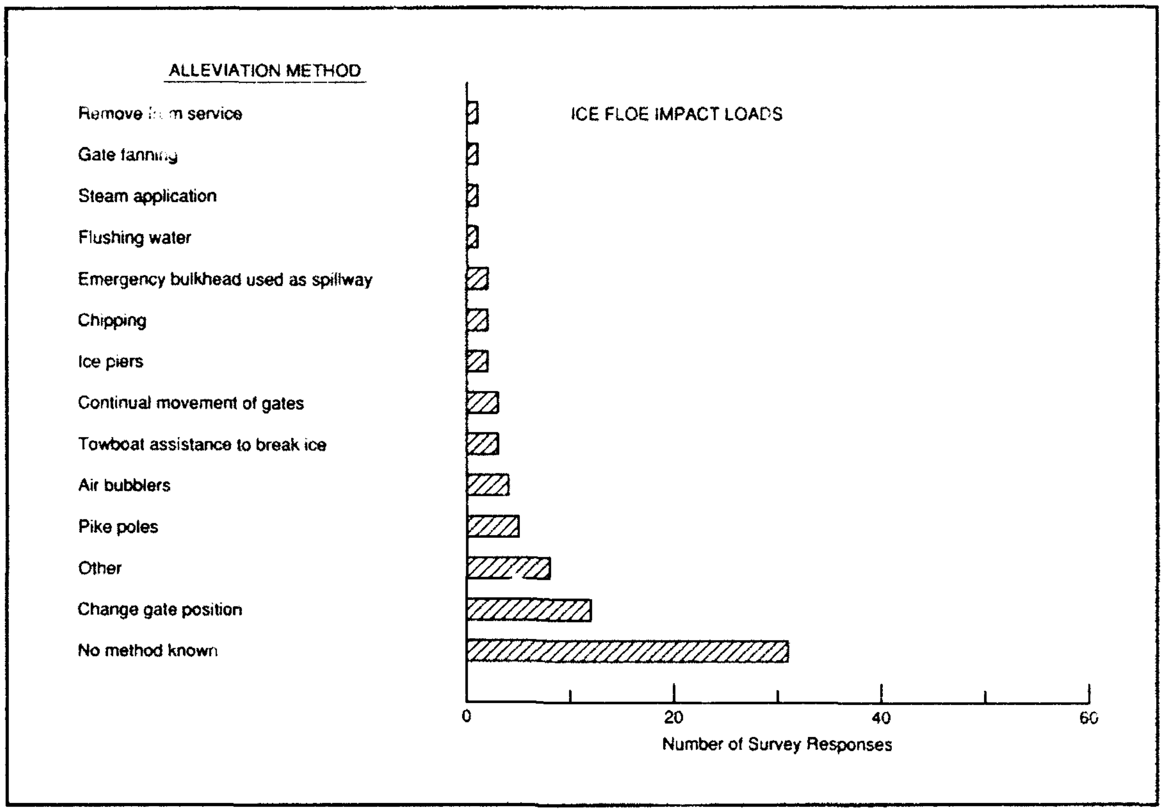

Figure 44. Ice floe impact loads, alleviation methods and number of responses

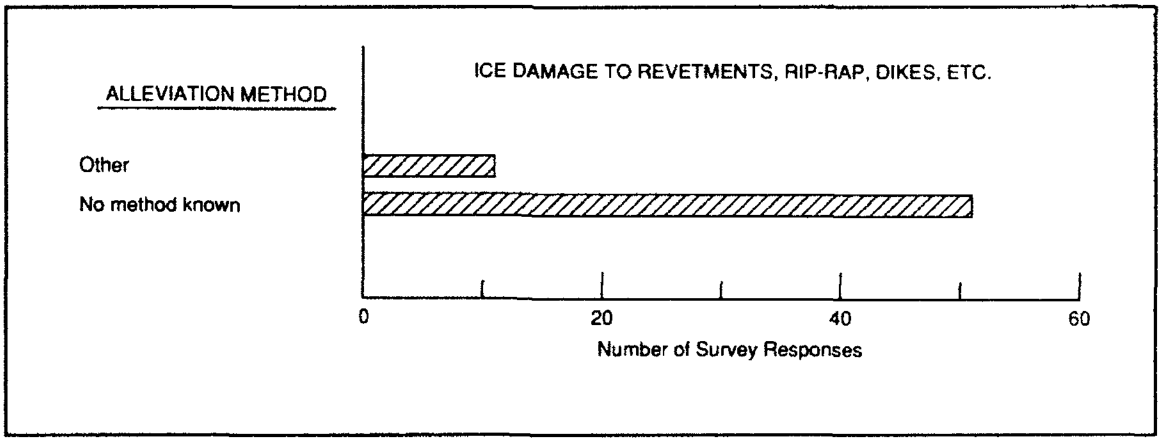

Figure 45. Ice damage to revetments, riprap, dikes, etc., alleviation methods and number of responses

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
April 1993

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Icing Problems at Corps Projects

5. FUNDING NUMBERS
WU32659

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, NH 03755-1290

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000;
U.S. Army Engineer Waterways Experiment Station, Structures Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Technical Report REMR-HY-10

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Icing of machinery such as dam gates, lock gates, gears, and seals is a problem at Corps projects during cold weather. A survey was distributed to Divisions and Districts to obtain information on icing problems and existing solutions. Results of the survey are presented in this report. Each solution is discussed in relation to the appropriate problems.

14. SUBJECT TERMS

Bubbler	Gates	Icing	Machinery
Dams	Ice	Locks	

15. NUMBER OF PAGES
54

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	